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To: rlg2@yktvmv.BITNET
Subject: draft FUSION PRODUCTS chapter
X-ANJE-To: GARWIN,SCHIFFER

four sides

4.7

Dear Dick

Enclosed the latest draft of the 'FUSION PRODUCTS' CHAPTER. I am to send a draft chapter to DOE for distribution this coming Monday the 9th. If I do not hear from you I will send the enclosed draft (with possible minor changes that I may get from others in the next few days).

Hz

About the draft: The material you sent me has been trimmed in various ways -- please check that it still makes sense.

1) I put the section on neutron detection into an appendix -- is that OK? Or should this be omitted? I have no strong feelings about it.

2) Several references need to be added, some of them may already be on the list at the end.

3) It is not clear to me that having the Fleischman & Pons gamma spectrum as a figure adds much, except that it rubs in the fact that they do not understand gamma detection. It seems to me to be beating a dead horse.

4) Likewise about the Frascati figure that you indicated.

5) I felt that you had somewhat overdone the Menlove business -- as I think I mentioned in an earlier note, several things you said (e.g. H2O control runs, separating counters) Menlove told me he had checked. I changed it but you should check and rewrite as you see fit.

6) I thought that too much was made of the BARC report in your writeup, giving it a lot of weight and leaving the reader up in the air. I cut it back -- feel free to change it.

7) I did leave the tables from the BARC report in as as appendix -- I think we should probably remove them (as well as the Bockris tables) if you agree.

8) I put in a table of neutron rates -- normalized to the published Jones rate. Could you please check this? Huizenga is worried that Jones quoted a slightly lower rate to us at the visit to BYU. But this was only in a hand drawn figure of comparisons, and I would prefer to stick with the published number -- otherwise people will be very confused.

9) Any other changes would be appreciated.

PLEASE NOTE THAT I WILL NOT BE ABLE TO COME TO THE MEETING AT CHICAGO. SO IT WOULD BE GOOD IF WE COULD TALK BEFORE THEN.

Regards, John Schiffer

Draft -- October 4, 1989

FUSION PRODUCTS

I. INTRODUCTION

The nuclear fusion of deuterium has been studied intensively for over 40 years. The reaction between two low energy deuterium nuclei can proceed in three ways:

(a) D + D --> 3He + n + 3.269 MeV

(b) D + D --> 3H + p + 4.037 MeV

(c) D + D --> 4He + gamma(23.847 MeV)

The reactions (a) and (b) have been studied down to deuteron energies of a few keV and the cross sections found to be equal to within 10%. In the interaction of deuteron beams with heavy ice or metal deuteride targets, almost one 2.45 MeV neutron is produced (with an accompanying 3He) for every triton (with an accompanying proton). This near-equality of neutron and proton branches of the D + D reaction, shown in figure 1, is a reflection of the basic symmetry of nuclear forces between proton and neutron, disturbed only slightly at the MeV energies of the emerging particles by the Coulomb interaction which is not symmetrical between proton and neutron. The cross sections for reaction (c) are very small -- on the order of 10**7 lower than the first two.

All nuclear reactions at low energies between two deuterons are retarded by the Coulomb repulsion between the positively charged nuclei -- the penetration of the repulsive Coulomb barrier changes exponentially with bombarding energy: for instance the measured cross section for reaction (b) changes from 0.2 microbarns at 2.7 keV to 35 millibarns at 100 keV. But the _r_a_t_i_o_s for the three reactions appear to be constant below 100 keV.

Any fusion between deuterium nuclei _m_u_s_t lead to detectable fusion products. For reaction (a) neutrons are the most easily detected product, by direct counting. For (b) the protons or tritons can be detected by direct counting, and the accumulated tritium could also be identified by its radioactivity, albeit with lower sensitivity. Neutron counting perhaps the most useful technique here, since neutrons must be produced by the energetic tritons interacting with other deuterons in the material at the rate of 1 neutron for every 10000 to 50000 tritons. reaction (c) leads to readily detectable high energy gamma rays, and 4He may be identified by mass spectroscopic measurements, but the sensitivity is low -- though the 10**17 levels implied by the 1 watt of heat should be readily observable.

In the following we wish to summarize the experimental evidence on these fusion products. First we discuss the plausibility of reactions at room temperature and the issue whether the constancy of the three reaction modes is a reasonable extrapolation to very low energies. Then the data on neutrons, charged particles, gamma rays and tritium are summarized. Finally, some comments are included on the more exotic explanations.

II. THE REACTION PROCESS.

Fusion reactions can occur only if, during a nuclear collision, the Coulomb barrier is surmounted or, at low energies, penmetrated and the nuclei approach each other within about 10**-12 cm, some 10000 times smaller than the typical separations in ordinary matter. Fusion is generally enhanced by a well-understood quantum mechanical phenomenon called tunneling that allows fusion to occur in collisions far less violent than might be required otherwise.

In the thermonuclear fusion that occurs in stars and in laboratory "hot fusion" experiments, very high temperatures provide the violent collisions required to produce fusion. However, in the so-called cold fusion experiments, it is claimed that the penetration of the barrier through quanum mechanical tunneling has somehow become so effective as to allow fusion to occur even at room temperatures. Further, some of the experimenters claim that the nuclear process is changed by some unspecified mechanism so as to alter dramatically the nature of the reaction products. These claims must be understood as separate and equally surprising.

Some simple calculations serve to illustrate how remarkable the claim of fusion at room temperatures really is. The fusion rate for the two deuterium nuclei in a deuterium molecule (where they are even closer than they are when embedded in a metal) results in one fusion per year in a solar mass of deuterium. Further, the fusion of protons and deuterons is 10**9 times faster than the D + D reaction claimed to have been observed (although it is still extraordinarily slow). There is no known mechanism by which these rates _c_o_u_l_d be enhanced by the 40-50 orders of magnitude required to agree with the reported observations.

One commonly invoked mechanism for enhancing cold fusion rates is screening by "heavy" electrons. It is true that endowing the electron with a hypothetical mass some 5-10 times larger than it actually has would enhance fusion rates sufficiently to agree with most cold fusion claims [Ko]. It is also true that there are "heavy fermion" materials whose thermodynamic properties at very low temperatures are characteristic of quasiparticles with masses many times those of a free electron. However, this phenomenon is understood as involving long-wavelength excitations in which strong correlations "dress" electrons near the fermi surface. As such, heavy fermions extend over many lattice sites. Because the tunnelling in nuclear fusion occurs at distances smaller than one lattice site, only the short-wavelength "bare" electron excitations are relevant for screening, and cannot enhance the fusion rate significantly.

IIa. The D + D Branching Ratios.

The relative rates of reactions (a), (b), and (c) are called the branching ratios and are a crucial issue in the discussion of some cold fusion claims. These reactions have been studied in laboratory experiments using accelerators for deuteron energies above a few keV [Kr]; the smallness of both cross sections prevents reliable measurements at lower energies. The ratio between the two rates exhibits a weak energy dependence and is near 1.0 at the lowest energies. Data from muon-catalyzed D + D fusion [muon], which probes the energy range around 3 keV is still consistent with equal rates.

A branching ratio of more than one million would be required to explain experiments that claim to observe high fusion rates (either through heat or tritium production) without a corresponding high neutron flux. As "cold fusion" is thought to occur at energies on the order of eV, this is not directly ruled out by the data discussed above. However, there is no known mechanism for inducing such a rapid energy-dependence in the branching ratio. The Oppenheimer-Phillips process involving the Coulomb break-up of the deuteron has been invoked in this regard [??].
However,
this mechanism requires the deuteron size (some 5 fm) to be large relative to the spatial scale (the Bohr radius) of the internuclear Coulomb wave-function. As this latter is some 25 fm for D + D, the Oppenheimer-Phillips

process cannot give rise to the large effects required.

IIb. The Gamma Branch.

Some researchers have hypothesized that the D + D -> 4He + gamma (23.847 MeV) reaction, which is ordinarily some 10**7 times weaker than reactions (a) and (b) in which two fragments are produced, somehow dominates in cold fusion situations. To be consistent with the lack of neutrons, a very large enhancement of the gamma branch by a factor somewhere in excess of 10**13 would be required. We know of no way whereby the atomic or chemical environment can effect such an enhancement, as this ratio is set by phenomena on a length scale some 10**4 times smaller than the atomic scale.

Even if there were such an enhancement, the absence of observed high-energy electromagnetic radiation (photons, positrons, or fast electrons) rules out such a mechanism. While direct coupling to the lattice through unspecified mechanisms has been invoked to supress such radiation, any such coupling must occur through the electromagnetic field and would result in some observable high-energy radiation.

IIc. It has been suggested an alternative fusion process, could be the reaction

p + D --> 3He + gamma (5.49 MeV)

for which the penetration factors are still overwhelmingly small at room temperature, but somewhat less so than for the D + D process. This reaction must produce a readily observable gamma ray. If it is to account for 1 watt of heat, then it should also produce 3He in observable concentrations.

IId. Estimate of Secondary Yields from Fusion Products.

i) ___Neutrons from tritium.___ The tritons produced in reaction (b) are produced with an energy of 1.01 MeV. This energy must be lost in the immediately surrounding material, which in the case of an electrolytic cell is either the Pd electrode saturated with deuterium, or heavy water. The tritons will therefore bombard the deuterium in the surrounding material. The t+d reaction is a rich source of neutrons, with a cross section that reaches 5 barns at 0.12 MeV, then falls to about 0.7 barns at 0.5 MeV, and reaches slightly below 0.3 barns at 1 MeV. For the 1.01 MeV tritons from the D + D reaction one may assume an average cross section of about 1.2 barns. For tritons that are stopped in PdD this translates into a neutron yield between 0.15 and 0.2x10**-4 neutrons per triton; for tritons stopping in heavy water there are about 0.9x10**-4 per triton.

ii) ___Coulomb excitation of Pd by protons___. The even Pd isotopes (104,106, 108,110) with abundances of 11,27,26,12 % have first-excited 2+ states at 555,512,434,374 keV and B(E2) values between 0.5 and 0.8 barns. The cross sections for Coulomb excitation are in the vicinity of 20 to 50 mb and thus the yields expected are 2 to 5 10**-6 per proton. In palladium the half thickness for absorption of these gamma rays is about 4 mm, in water it is several cm.

In terms of power, there must be about 10**8/sec secondary neutrons per watt of fusion, even if direct neutron production is completely suppressed and all the reaction goes into tritium production.

Under these conditions there must also be slighly under 10**7 secondary photons per second in the 500 keV range.

III. NEUTRONS.

IIIa. Detection.

As discussed above neutrons are a major product of D + D fusion. Neutrons are very convenient particles to detect, since they interact only with the nuclei of atoms and so can emerge from reaction vessels of substantial size unscathed and without having lost any energy. Similarly, large counters can be used without the problem of thin entrance windows, since neutrons enter into the mass of the counter without difficulty. Neutron detection is summarized in Appendix A.

IIIb. Selection of Data.

In what follows, we have tried to use published material, where available, or material prepared for publication and presented at formal meetings or as preprints distributed without restriction as to citation. It is important to include not only _p_o_s_i_t_i_v_e results, that claim the detection of neutrons, but also the _n_e_g_a_t_i_v_e ones, that have attempted to replicate the experimental procedure of the former and failed to detect neutrons at a level of sensitivity substantially better than the positive results.

IIIc. Initial claims.

The University of Utah (UU) group in its i_n_i_t_i_a_l publication [Fle] claimed the detection of neutrons from D + D by virtue of the gamma ray emitted by the capture of the moderated neutron in the water bath surrounding the electrolytic cells. A very narrow peak in the pulse-height spectrum from the NaI scintillator was shown in the paper, and is reproduced in figure 2
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at the expected energy of 2.2 MeV. The text, however, claimed that the expected energy was 2.5 MeV 2.45
RLG check
and so narrow a window of the overall scintillation spectrum was shown that the reader could make no judgment as to the reality of the peak.

These very questions were taken up by a group at MIT, [Pe] who showed that the photo peak at 2.2 MeV obtained at MIT from Cf spontaneous fission neutrons moderated in water and radiatively captured on protons is accompanied by other peaks from natural background that enable one to calibrate the energy, and successive interchange between UU and MIT groups in the scientific literature ~~have~~ demonstrated with high probability that the claimed detection of neutrons by the proton capture gamma ray at UU has been an artifact of the experimental apparatus.

The original publication from Brigham Young University (BYU) [Jo] presented the detection of neutrons as the sole experimental evidence for the existence of cold nuclear fusion. The neutrons were detected in a two-stage neutron counter -- first by the proton recoil in organic scintillator, followed within a few tens of microseconds by a signal from the capture of the moderated neutron on boron viewed by the same photomultipliers. This double detection of a single neutron serves substantially to reduce the ambient background due to gamma rays, although

there remains background in the experiment due to gamma rays and to real neutrons from cosmic rays* and other sources. The group at BYU has chosen to attempt to vary the experimental conditions in order to obtain a greater rate of D + D fusion, and so has not presented much more data than the original paper on the detection of neutrons with that counter. In fact, BYU has been working in collaboration with other groups, notably at LANL [??], [Mel], and also with ~~a group at Yale University.~~ [??] The original claim of neutron detection five standard deviations above the background is somewhat reduced in statistical strength if one considers the degrees of freedom that are fixed by the presentation of a peak in one of a number of experiments and at a particular energy, and also the possible fluctuation in the cosmic-ray neutron background. Ordinarily, however, such a significant result can be brought up from the background by using different counting or detection equipment or by reducing background through improved shielding or by moving to underground site.

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*(footnote) Additional care is needed as the rate of cosmic ray neutrons can fluctuate by 20% or more with variations in barometric pressure as well as with solar activity.

Typical of the latter is work presented by the group at Sandia National Laboratory, [Sa] **RLG cite** in which a site was found with substantially less background and results presented as follows for the neutrons produced in electrolytic fusion. [Jo] **RLG cite** ???Should we also cite Frejus results presented at Santa Fe???

Many claims have been made for the production and detection of neutrons produced in electrochemical cells, but these claims have almost all been withdrawn or moderated by the discovery of difficulties with the counter -- particularly with the BF3 counters used. In some cases, the counters are sensitive to humidity; in others to microphonic noise (vibration); or to other afflictions. A summary of some of the limits on neutron fluxes reported, compared to the flux reported by the BYU group, is shown in Table I.

IIId. Dry Fusion.

Results presented in April 1989 by a group at Frascati [DeN] opened an entirely new opportunity for the observation of D + D cold nuclear fusion. In this work, deuterium gas at 60 atmospheres pressure (60 bar) was allowed to contact titanium lathe turnings in a stainless steel reaction vessel. That allowed the temperature of the sample to be varied either by heating or by cooling. No neutrons were observed from the hydriding reaction at room temperature or at elevated temperature, when viewed by a nearby BF3 counter. However, after cycling to nitrogen temperature, _b_u_r_s_t_s of counts were obtained from the counter -- typically on the order of 20 counts per burst emerging over a period of 60 microseconds. One set of data was presented on counts obtained by cycling to nitrogen temperature, showing neutrons essentially only in these bursts.

A totally different type of neutron emission was also claimed by

the Frascati group [DeN] following warming from nitrogen temperature over one weekend. A bell-shaped curve rising to a peak of 300 neutrons per ten-minute counting interval is reproduced in figure 3.
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This, of course, is an important experimental result, and provoked great effort toward verification both at Frascati and elsewhere. It is understood from private communication from M. Martone at Frascati that there has been no confirmation of either the burst results or of the continuous neutron emission from the D-Ti system or from any other dry fusion activity at Frascati. In addition, electrochemical cells operated without producing observable numbers of neutrons, and their operation was terminated during the month of July.

A group at LANL [Me] has conducted dry fusion work with Ti and Pd, and has presented results both at the Santa Fe meeting and in a preprint. This group at LANL uses high-efficiency systems that moderate any fast neutrons emitted from experimental cells, detecting the moderated thermal neutrons in 3He gas counters.
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Bursts of neutron counts are sometimes observed 3000-5000 seconds after the sample is removed from liquid nitrogen, at a time when the sample temperature is typically -30 C. These bursts, consisting of about 100 neutrons at most, are seen in about 30% of the samples tested. An attempt to reproduce this effect at Sandia National Laboratory yielded entirely negative results.
[??]

At the Santa Fe workshop, Moshe Gai of Yale presented results obtained in collaboration with Brookhaven National Laboratory, in which no neutrons were detected from electrolytic cells.

Finally, a conference report from the Bhabha Atomic Research Center (BARC), [Iy] provides text and tabulated results from several groups at BARC. Fig. 1 of the BARC report shows counts from neutron detectors observing a large electrolytic cells, with an estimated 2x10**7 neutrons in the 5 minutes following an overpower trip of the electrolyzer. Fig. 2 of the BARC report shows dry fusion 3He counter output during gradual rise of temperature of 20 g of Ti while deuterium gas was being pumped off. It is also commented that samples could be loaded with deuterium gas at 1 bar and 900 C, and that "one such disc shaped button loaded on Friday 16th June began emitting neutrons on its own, almost 50 hours after loading. It produced (about) 10**6 neutrons over a 85-minute active phase. The background neutron counter did not show any increase in counts over this time."

IIIe. Secondary Neutron Production.

There are severe problems of consistency between the number of tritium atoms found in some of the experiments discussed above and the number of neutrons detected. The BARC abstract reads, "The total quantity of tritium generated corresponds to about 10**16 atoms suggesting a neutron to tritium branching ratio less than 10**-8 in cold fusion."

But, as discussed above there _m_u_s_t be at least one neutron per 100,000 tritons if the observed tritium were is originating from fusion, _1_0_0_0 times more than was observed!

IV. CHARGED PARTICLES AND GAMMAS.

A few experiments [Po,Pr,Re,Su] to measure the 3 MeV protons and/or the 1 MeV tritons produced in the reaction, D + D --> 3H + p, have been reported; they are summarized in Table II below. A variety of different methods has been used, but the lowest limit on charged-particle production appears to be that set by Price using plastic track detectors. Their setup was designed so that the light water control cell matched the heavy water cell as closely as possible. Electrolysis was performed for 13 days, and the cathode stochiometry was determined to be Pd(H,D)0.8. Both cells showed track production rates which agreed and were consistent with the alpha-particle emission rate for native Pd foils due to trace (ppm) impurities of the natural 238U and 232Th decay chains; however, no tracks due to protons with energies between 0.2 and 3 MeV or tritons with energies between 0.2 and 1 MeV were found. From these data Price [Pr] set limits on the fusion rate of less than 0.002 per cm3 per second. This value results in an upper limit of 8.3x10**-26 fusions per dd pair per second. This is about an order of magnitude lower than the limits obtained using Si surface barrier (SSB) techniques.

A limit on the fusion rate of 0.028 per cm3 per second or 1.2 x 10**-24 fusions per dd pair per second was obtained by Ziegler [Zi] using a SSB technique. Porter [Po] used a SSB detector to view the back of a 76 micron thick Pd foil cathode ina heavy water electrolysis cell. They obtained a limit of less than 6x10**-25 protons per dd pair per sec at the 2 sigma level; chemical analysis of their electrolytes showed no evidence for anomalous increases in tritium concentrations. Sundqvist et al. [Su] also used a SSB technique to detect protons. The detector was placed close to Pd foil cathodes which were thin enough to allow all the protons produced to escape from the foil. All of their runs gave a result of 0 within the statistical errors, resulting in a fusion rate of -2.1 (+/-2.2) x10**-24, if a bulk process is assumed.

Recently, Rehm [Re] has reported using a proportional counter to search for charged particles from electrolytic cells with Pd and Pt electrodes in 0.1 M LiOD in D2O. They obtained an upper limit of 4 x 10**-23 fusions per dd pair per second, not as low as the limits using the other methods.

In summary, a variety of experimental techniques has been used in searches for charged particles; all of them set very low limits on fusion occuring via the D + D --> 3H + p. Most of these results set limits on fusion via this channel that are considerably less than Jones' [Jo] value of 1.00 (+/-0.82) x 10**-23 fusions per dd pair per second for the D + D --> 3He + n channel obtained from neutron measurements. (The uncertainty was calculated by [Su]).

The upper limit of Price [Pr] of 8x10**-26 fusions per dd pair per second is much below the average low rate inferred from the neutron measurements of Jones or even those of Menlove [Me]. The extremely low limits which the searches for charged particles (either protons or tritons) place on their production is clearly inconsistent with the reported production of tritium via the cold fusion reaction.

IVa. GAMMA-RAY SEARCHES

As was mentioned above, a ~~small~~ rare branch of the D + D reaction proceeds through capture, in which a 23 MeV gamma-ray is emitted. Similarly, the p + D reaction is associated with a 5.49 MeV gamma ray.

Several searches have been published in which no gamma rays that would be associated with the D + D or p + D capture reactions were seen. They include a report by Henderson [He] who cites limits around 10**-23/sec 23-MeV gamma rays emitted per deuteron in various cells. Porter [Po] reports no 5.5 MeV gamma rays -- though no absolute limit is quoted. They also comment on the absence of Pd K X-ray production. Greenwood [Gr] also report limits of 10**-23 for gamma rays above 1.9 MeV. Other negative results are quoted in the Santa Fe abstracts without quantitative detail.

V. TRITIUM.

As discussed above, one branch of the D + D reaction produces tritons and protons. As was also discussed, searches involving the direct detection of charged particles have yielded rather stringent negative results. A number of searches have also been made for the tritium accumulated during the electrolysis of D2O with palladium cathodes, determining tritium content by detecting the radioactive decay of tritium. In such experiments it is important to determine the initial tritium content of the heavy water and to take cognizance of the fact that the electrolysis of the heavy water will enrich the naturally occurring tritium in the heavy water.

The detection of tritium by measurement of its beta decay is inherently a less sensitive probe of the D + D reaction than the direct measurement of neutron production or charged particle production. About 10**7 tritium atoms give 1 decay by beta emission per minute. The tritium content of normal water is about 10**-18 relative to hydrogen but, as discussed in Appendix C the normal manufacturing of heavy water also enriches in tritium and thus heavy water currently being sold gives between 120 and 180 disintegrations per minute (dpm) from tritium decay.

Va. Null Experiments.

Most of the work reported to date on the search for excess tritium produced in electrolytic cells can be accounted for by the electrolytic enrichment process. This includes the original report by Fleischmann and Pons Fle, and experiments at ANL, Gre,Red BNL, Da,McB,Wi2 Cal Tech, Le2 CRNL, Sc INEL, Lo LLNL, Al NRL, Er ORNL, Fu,Sc Sandia, Na SRL, Ra Texas A & M, Ma and Utah. Wad

Vb. Tritium Bursts.

A small number of experimenters report occasional irreproducible amounts of excess tritium in their D2O samples taken from their electrolytic cells after days of operation. This includes observations by Storms St at Los Alamos, and Fuller [Fu] and Scott Sc at ORNL. The ORNL experiments show single cases of an excess of tritium which is of short duration, after which a cell returns to background level. Storms reports excess tritium, 100 times background, in two cells out of fifty.

Vc. Closed Cells - Correlation with Excess Heat.

Four different groups [McB,McC,Sc,Ma] have now looked for tritium production in closed electrolytic cells. These experiments detect all the tritium from the electrolytic process with the exception of that which may be contained in the Pd cathode. In general, the deuterium inventory in the cathode is negligible compared with the D2O. Only that tritium formed within the cathode and which remains there because of slow diffusion is unaccounted for. There is no electrolytic enrichment of the tritium in the

make up D2O. In these experiments the total amount of excess tritium found in the total D2O is less than 10**4 T atoms/sec. If this tritium is produced by the D + D reaction, then the maximum amount of excess power (cold fusion power) is 10**-5 milliwatts. In one experiment [Wad] in an open cell there was a heat burst of 35 watts for 90 minutes (187,000 joules). The tritium was measured after the burst and no excess above the electrolytic enrichment was found. Clearly the heat burst does not come from the D + D reaction.

Vd. High Levels of Tritium.

Two groups [Pa,Iny] find tritium at levels of 10**12 to 10**14 T atoms/ml D2O after periods of electrolysis of the order of hours. This amount of tritium cannot be produced by electrochemical enrichment with the D2O volume reductions reported. The results of the Bockris [Pa] group at Texas A & M for cells in which excess tritium was found are given in Table 1 of their paper, reproduced in Appendix B. Excess tritium is not found in all of their cells. A listing of cells in which no excess tritium was found is given in their Table 4 (also in Appendix B). The Bockris cells are 0.1 M in LiOD and have nickel anodes. They precipitate nickel oxide during the electrolysis; some nickel is also electroplated out on the palladium cathode. In one experiment, A8, the specific activity of the D2 gas produced by the electrolysis was measured. It is 100 times that of the electrolyte.

D2(gas) containing tracer amounts of tritium and in equilibrium with D2O(liquid) has a specific activity that is lower by 0.6 than the D2O (liquid). If the tritium is formed during electrolysis, this result suggests that it is formed in the chemical species DT and that the tritium in the liquid D2O is the result of hot atom processes or slow isotopic exchange of the DT(gas) with D2O(liquid) [Bi2].

Wolf [Wo] at Texas A & M have looked for neutron production in Bockris type cells. An upper limit to their neutron production rate is 1 neutron/second, which is 10**-10 times that of the tritium production rates reported with similar cells by Packham et al. [Pa] This is a large discrepancy from the equal production rates for neutrons and tritons required by the branching ratio in the fusion reaction, discussed in section II, and is inconsistent, by a factor of 10,000 to 100,000, even with the secondary neutrons that _m_u_s_t accompany the tritons produced from nuclear fusion. One is strongly inclined to conclude that the excess tritium found in the electrochemical cells cannnot be the result of nuclear fusion in the cell.

The most extensive and systematic search for tritium in the electrolysis of D2O with Pd cathodes has been carried out by Martin [Ma] at Texas A & M. He has used both open and closed cells. His cathodes come from either Johnson & Mathey, a major supplier, or Hoover and Strong, who supplied the cathodes to the Bockris [Pa] group. He has operated cells with Pt, Ni wire and Ni gauze (obtained from Bockris) anodes. In none of his cells does he find any excess tritium beyond that expected from electrolytic enrichment. Nor does he find any neutrons. Two of his cells produced excess heat but no tritium. In short, he has been unable to reproduce the results of the Bockris group.

The BARC [Iy] group have found amounts of tritium comparable to the Bockris group in the D2O electrolyte from cells in which electrolysis was carried out for a few days with currents varying between 1 to 100 amperes. As was already mentioned above, here there is again a factor of 1000 internal inconsistency between their measured neutron yields and the

neutrons that have to be there if this tritium was indeed produced by fusion -- even if one assumes the very unlikely drastic modification of the branching ratio in the D + D reaction.

The experiments carried out to date include the large number of null experiments. There are a few experiments in which excess tritium is found, and which other groups have not been able to reproduce. These measurements also contain a serious internal inconsistency, in that the ratio of measured neutrons to tritium is smaller by orders of magnitude than what is consistent with a fusion process being their source. Additional investigations are desirable to clarify the origin of the excess tritium which is occasionally observed.

VI. EXOTIC EXPLANATIONS.

The data on fusion products, even where positive results are reported, give rates far below those that would be expected from the levels of heat reported in some electrolysis experiments. There have been some attempts to propose mechanisms where the reaction heat from the D + D --> 4He process would go entirely into lattice heat, rather than a photon [Wal,Ha]. Analogies have been made with the internal conversion process, and with the Mossbauer effect. Neither of these analogies is applicable to 4He.

Internal conversion allows an atomic electron of an excited nucleus to carry off the reaction instead of a photon. This process is understood quantitatively -- it is dominant in heavy atoms with tightly bound inner electrons and for low energy (less than 1 MeV) photons. In helium the atomic electrons are loosely bound and the photon is 23.8 MeV -- there can not be any appreciable coupling between the photon and the atomic electrons, and internal conversion or any related process cannot take place at anywhere near the rate that would be required.

In the Mossbauer effect the _m_o_m_e_n_t_u_m of a very low energy (below 100 keV) photon is taken up by the entire lattice in a coherent mode, but _n_o_t its energy. The process cannnot be relevant to the present process.

Considering experimental evidence more generally, there have been careful studies of a very large number of reactions analogous to the D + D fusion process, in which gamma rays of comparable energy emitted from low-energy nuclear reactions (thermal-neutron capture gamma rays) and the cross sections for cpature have been studied very carefully and quantitatively. Their knowledge is essential to the operation of fission reactors. If there were any anomalous processes in which the energy of a capture gamma ray were converted into lattice heat, this would have almost certainly been noticed as a discrepancy in cross sections with major implications on the operation of reactors. After four decades of extensive study of the processes relevant to the operation of fission reactors the possibility is extemely remote that an entirely new process, that could dominate these nuclear reactions, would have remained hidden.

VII. SEARCH FOR PRODUCTS OF COLD-FUSION IN THE EARTH

Products of low-level cold fusion have been inferred to be produced by natural geologic processes [Jo, Jo1]. The 3He:4He ratio is anomalously high in volatiles from deep-source volcanoes such as Hawaii, Iceland, and Yellowstone [Cr,Ku,Mam]; anomalous 3H is also suggested by fragmentary data [Om,Jo2], and production of other radiogenic products such as 36Cl have

been predicted [Pk]. Although the high 3He values have previously been considered relict from early earth processes, presence of anomalous 3H or 36Cl (beyond that due to bomb tests) would be definitive evidence of natural cold fusion at depth within the earth. Implications would be major for geophysical problems such as heat-flow modelling, element-distribution with depth, and composition of the Earth's core.

Although some knowledgeable isotope geochemists see no evidence for naturally occurring cold fusion [Cr1], several government and university labs are searching for evidence of such fusion processes as recorded by volcanic volatiles [Jo2,Ky,Go,Loc,Qu]. Even if laboratory experiments for cold fusion are discredited, such geologic studies could add much to understanding of the behavior of volcanic volatiles. No rigorous results are yet available, but experiments proposed or underway at Brigham Young, Los Alamos, Lawrence Livermore, New Mexico Tech, and the U.S. Geological Survey (Denver) should yield data within 6 months to 1 year.

VIII. SUMMARY.

A number of careful experiments have been carried out to search for the expected products of cold fusion. _N_o_n_e have seen these products at anywhere near the level that would be expected from the heat production reported in electrolysis, by many orders of magnitude. Some experiments report neutrons or tritium at a much lower level -- however, the rates of these two fusion products (measured in the same experiments) are inconsistent with each other, again by large factors.

The neutron bursts reported in some experiments also suffer from not being reproducible by other experimenters. While it is conceivable that some mechanism might produce very small bursts of hot fusion (e.g. high voltage internal sparks associated with fracture of the material at certain temperatures) at the present time the experimental evidence is not redily reproducible, and if real, the phenomenon does not appear to be related to 'cold fusion' as postulated in the heat production experiments.

If there _w_e_r_e such a process as room temperature fusion, it would require not only

(a) the circumvention of fundamental quantum mechanical principles, that have been carefully tested against numerous measurements of barrier penetration (such as the systematics of spontaneous fission and alpha radioactivity lifetimes and those of nuclear cross sections), but also
(b) drastic modifications of branching ratios in the D + D reaction, _a_n_d
(c) the invention of an entirely new nuclear reaction process.

> 'Alice laughed. "There's no use trying," she said: "one can't believe impossible things."
>
> "I daresay you haven't had much practice," said the Queen. "When I was your age, I always did it for half-an-hour a day. Why, sometimes I've believed as many as six impossible things before breakfast."'
>
> from 'Through the Looking Glass'

TABLE I. SOME COLD FUSION NEUTRON RATES

Authors	Reference	Neutrons per DD pair per sec (Volume yield)	Normalized Neutron Yield
Yield corresponding to 1 watt of heat production	[Fle]	3x10**-11	3x10**12
Yield corresponding to neutron yield of Jones et al	[Jo]	10**-23	1
Gai et al	[Ga]	< 2x10**-25	< 0.02
Kashy et al	[Ka]	< 10**-25	< 0.01
Lewis et al	[Le]	< 1.5x10**-24	< .15
Williams et al	[Wi]		< 0.2
Alber et al	[Alb]	< 5x10**-25	< 0.05
Broer et al	[Br]	< 2.2x10**-24	< 0.2
Schriber et al	[Schr]		< 0.02
De Clais et al	[DeCl]		< 0.01 < 0.001

TABLE II. SOME COLD FUSION FAST CHARGED PARTICLE RATES

Authors	Reference	Protons per DD pair per sec	Yield Normalized to Jones et al. neutrons
Yield corresponding to 1 watt of heat production	[Fle]	3x10**-12	3x10**12
Jones et al.	[Jo]	1x10**-23	1.0
Porter et al.	[Po]	< 6.7x10**-25	< 0.07
Price et al.	[Pr]	< 8.3x10**-26	< 0.008
Ziegler et al.	[Zi]	< 1.2x10**-24	< 0.12 [a]
Rehm et al.	[Reh]	< 4x10**-23	< 4
Sundquist et al.	[Su]	< 2x10**-24	< 0.2

Schrieder et al.	[Schr]	< 3.1x10**-24	< 0.31 [a]

[a] 6. Rehm et al comment that the choice of the low-energy cutoff (e.g. 1 MeV in Ref. [Zi]) restricts the emission angle of the protons with respect to the foil to a small cone representing only a few of the total solid angle. This effect seems to hve been neglected in the efficiency calculations for the limits quoted by these authors.

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APPENDIX A

Neutrons can be detected either at their initial energy in the MeV range ("fast"), or after they have lost energy by successive collision with light material -- particularly hydrogen ("moderation.") The detection of fast neutrons can be achieved by photomultiplier tubes viewing the proton recoil in plastic or liquid scintillation material. _S_l_o_w neutrons (those that have lost almost all their kinetic energy and are in thermal equilibrium at room temperature) are conventionally detected by the charged particles produced when the neutron is captured with high probability in the nucleus of an atom of 10B (producing an alpha particle), or in a 3He nucleus, producing a recoil proton. A noble gas, 3He is used in the form of a proportional counter, while boron can be used either in the form of BF3 proportional counters or in the solid form, with the boron immersed in plastic or inorganic scintillator viewed by photomultiplier.

Additionally, neutrons can be detected after moderation by their capture in some material of very high capture cross section (such as

cadmium Cd), which produces several gamma rays that may, in turn, be detected by a photomultiplier viewing a scintillation detector. Similarly, neutrons moderated in water are almost entirely captured on the protons ("radiative capture"), giving rise to a deuteron plus a gamma ray of energy for the threshold of photodisintegration of the deuteron-2.2 MeV.

Finally, moderated neutrons may be captured in a trace element in the moderator (silver is a detector of choice) to produce a radioactive material that can be transported away from the experimental apparatus and counted separately with high efficiency at low background. The emitted radiation is typically a beta ray (negative electron), or a characteristic gamma ray following the beta decay. Of course, the world has enormous experience since the 1930s in detecting neutrons and in detecting neutrons from the D + D fusion reaction.

APPENDIX B

????COULD WE DO WITHOUT THIS????

Reproduce BARC tables

Reproduce Bockris tables

APPENDIX C Considerations in tritium concentrations.

Tritium is produced in the atmosphere by cosmic ray bombardment. Most of the cosmic ray produced tritium ends up in the oceans and in rivers. The "natural" abundance of tritium varies widely and was greatly increased by atmospheric testing of thermonuclear weapons in the '50s and in the early '60s. The order of magnitude of tritium in ordinary water is T/H - 10**-18 (1 TU). Sources vary from 1 to 200 TU. The production of heavy water from ordinary water is even more efficient in the enrichment of tritium than deuterium from the feed material. Most of the heavy water currently available is produced by the H2S - H2O dual temperature exchange process (GS process). The tritium content of fresh heavy water produced by the GS process is 68 dpm/ml D2O/TU feed. Processes which are more efficient than the GS process in heavy isotope enrichment will have a minimum tritium specific activity of 50 dpm/ml D2O/TU feed. Heavy water currently being sold on the open market has a specific activity in the range 120 - 180 dpm/ml D2O. There are sources with a specific activity as high as 10**4 dpm/ml

Most of the work done to date on the search for tritium produced in the electrolysis of D2O in cells with palladium cathodes has been done in open cells. The measurements are frequently limited to assays of the specific activities of the starting D2O and the electrolyte after electrolysis. In general, there have been periodic additions of D2O to replace the D2O decomposed to form palladium hydride and D2(g). To determine how much tritium, if any, has been produced requires a complete inventory of the tritium at the beginning and end of the experiment. From the data on the current and duration of the electrolysis it is possible to estimate the amount of D2O which has been electrolyzed. Electrolysis will enrich the tritium in the D2O of an electrolytic cell. The amount of enrichment is primarily a function of the amount of water electrolyzed for a given type of cathode. It can reach a factor of 5 when 95% of the initial charge of water is electrolyzed. Thus a careful analysis of an electrolytic experiment must be carried out if one is to interpret tritium specific activities after electrolysis below 1000 dpm/ml D2O as anything other than electrolytic enrichment [illegible].

Energy Research Advisory Board
to the
United States Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
(202) 586-5444

October 3, 1989

To: Cold Fusion Panel

Enclosed are responses to Dr. Biernbaum's July 15 request for information, circulated for your information and use. Also enclosed are three newspaper clippings,

William L. Woodard
Panel Secretary

Enclosures

Tennessee center's 'energy generator' yielding curiosity

By Associated Press

COLUMBIA, Tenn. — Scientists from Texas A&M University are the latest to beat a path to the door of Santa Fe Research Center in Columbia, where an inventor has a machine he says yields between four and five times as much energy as goes into it.

Company President Andy Brooks said Wednesday the machine, which he calls simply "an energy generator," has been tested at the University of Tennessee Space Institute and inspected in Columbia by teams from the Oak Ridge National Laboratory and Texas A&M.

"In our tests we're getting about 4.5 times the energy in," Brooks said. "We've had some better and we've had some worse, but all of them were repeatable."

The machine was invented by Joe Champion, the other half of the Santa Fe Research Center, who according to Brooks has been working on it for 17 years.

So far the results found by Brooks and Champion have not been repeated in independent tests.

Omourthe Velev, a chemist at Texas A&M who visited Columbia this week, said Wednesday the tests he saw yielded only about 1.1 times the energy put in.

"I would say we have mixed thoughts," Velev said. "From one point of view, it's interesting equipment. From another, what we saw Tuesday was not very convincing.

> *"For sure there is something unusual. If it is a nuclear fusion reaction, then we're OK. If it is not, then we want to understand it. It might still be interesting."*
>
> Omourthe Velev
> Texas A&M chemist

"Mr. Champion gave us some results that were very impressive," Velev added.

Velev said the Texas A&M researchers will continue to look into the generator. He said the method of measuring heat output used by Champion appears sound, and it could be that the results of Tuesday's experiments were a result of a mistake of some kind.

"For sure there is something unusual," he said. "If it is a nuclear fusion reaction, then we're OK. If it is not, then we want to understand it. It might still be interesting."

The Santa Fe instrument differs from the so-called "cold fusion" experiments at the University of Utah that so excited the scientific community in March.

That device used palladium and platinum in a solution of heavy water to create what the inventors said was a nuclear fusion reaction at room temperature.

The Santa Fe device, on which the company has a patent, uses radio frequency energy, seven electrodes and coils of copper wire suspended in a solution of water, salt and deuterium oxide, or heavy water.

The reaction chamber is a cylinder 5 inches in diameter and 28 inches long.

Brooks said tests at the Santa Fe lab put about 48 watts of power into the cylinder and got more than 200 watts out.

"We don't believe the reaction is chemical," Brooks said. "Joe (Champion) calls it a room temperature nuclear reactor. There has to be some sort of nuclear reaction going on inside, but nobody knows what."

Joel Muelhauser of the UT Space Institute said the original battery of tests on the machine had to be suspended but will resume after Labor Day.

UTSI officials reported in late July that in one 40-minute test, the machine appeared to have yielded 40 percent more energy than was put into it. The UTSI scientists were cautious in assessing the significance of that test, however, stressing that further experiments were essential before anything positive could be known.

State to look at temporary job agencies

News-Sentinel Nashville bureau

NASHVILLE — A special legislative committee Wednesday began a study of whether some temporary employment agencies may be set up as a ruse to avoid payment of employee benefits.

"We need to unravel this thing," said Rep. Ken Givens, D-Rogersville.

James Neeley, president of the Tennessee Labor Council, said the [illegible] hired by tempo-

Washington Post 10/2/89

SCIENCE
NOTEBOOK

Physics: Cold Fusion and 'Heat Surges'

Cold fusion is no longer a hot topic in most physics departments, but the University of Utah, which started the furor last spring, is carrying on. It has created a new department, supported by $4.3 million in state funds, and named it the National Cold Fusion Institute.

When Utah's Stanley Pons and a British colleague, Martin Fleischmann, claimed to have achieved nuclear fusion in a jar, thousands of physicists everywhere were skeptical but couldn't resist trying the apparently simple experiment themselves. They failed in overwhelming numbers and complained that Pons and Fleischmann had wasted their time by making extraordinary claims and not providing even ordinary supporting details.

Pons and Fleischmann stuck to their guns but refused to divulge any technical details, calling them proprietary information. Even though cold fusion has not been proven real by any generally accepted standard, University of Utah officials focus on its commercial potential. Unlike many strictly research outfits, the new institute has a director of corporate development.

A statement from Utah's public relations office said that in the last four months scientists there had recorded at least nine "heat surges" in the cold fusion apparatus that "provide partial confirmation of the Pons-Fleischmann experiments."

The institute's director, Hugo Rossi, however, told the Associated Press that recent experiments have shown no sign of fusion. "We have a conference coming up here next February. If we don't have any papers to present, then this place will be closing up shop."

—Boyce Rensberger

The Salt Lake Tribune
Salt Lake City, Utah
Aug 24, 1989

Japan Moving Ahead on Cold Fusion

Editor Reports India Boosts Effort, Too

By Tim Fitzpatrick
Tribune Staff Writer

The editor of an Asian science and technology journal said Wednesday that scientists in Japan have organized an Institute of Fusion Science and are rapidly moving ahead in cold fusion.

"Japan is the most organized of all the countries," said Ramtanu Maitra, editor of Fusion Asia, a journal of energy and other technology issues published in New Delhi.

Mr. Maitra was in Utah to see fusion scientists at the University of Utah and Brigham Young University. He met with BYU physicist Paul Palmer Tuesday and with U. of U. College of Mines Dean Milton Wadsworth and National Cold Fusion Institute Director Hugo Rossi Wednesday.

Mr. Maitra has a master's degree in nuclear physics from the State University of New York at Stonybrook, but he said he came to Utah as a scientific journalist, not a nuclear scientist.

Mr. Maitra said the institute was set up Aug. 1, and some 80 scientists will join under the leadership of Hideo Ikegami, a respected scientist.

He said the Japanese are very cautious and would not embark on such a thing unless it was worth pursuing. "They have found something. It's very clear."

University of Utah officials, in their bid for fusion funding, have repeatedly raised the specter of Japanese scientists using an organized effort to commercially exploit cold fusion before the United States.

He also said the Japanese tend to take a long-term approach to their research. "They won't get very euphoric, but they won't get very discouraged, either.... You have to get out of the mind-set that if it doesn't happen fast, it doesn't happen at all.

"We have to remember that Japan has an advanced hot-fusion research base," Mr. Maitra said. "This is not something totally new for them."

The Japanese have been closed-mouthed about fusion, he said. "It's very difficult to get information.... They are probably doing a lot more."

But he believes they will eventually be willing to publish more on fusion than their U.S. counterparts, who tend to classify such research

See B-2, Column 3

Japan Reported Moving Ahead On Cold Fusion

Continued From B-1

for national-security or patent reasons.

Mr. Maitra also said his own country, India, has stepped up its cold-fusion efforts at the country's nuclear research centers, including the Trombay Nuclear Research Center. Trombay, about 20 miles from Bombay, has 12,000 scientists, he said.

One Indian group has built a five-foot-tall cathode for a cold-fusion cell, which far exceeds anything built in the United States. "They wouldn't have gone for it if they weren't seeing anything significant," he said.

He said Asian scientists are acutely aware that cold-fusion research was launched in Utah, and several of them expressed envy that he was visiting here.

Saltmarsh
Grogan
Von Hollo

TEXAS A&M UNIVERSITY
DEPARTMENT OF CHEMISTRY
COLLEGE STATION, TEXAS 77843-3255

July 25, 1989

(409) 845-2011
FAX (409) 845-4719

Dr. Howard K. Birnbaum
Materials Reseach Laboratory
104 South Goodwin Avenue
Obanna, Illinois 61801

Dear Dr. Birnbaum,

I received your "Dear Colleague" letter about cold fusion and have distributed it to the 5 colleagues who are directing groups of research on cold fusion at Texas A&M.

The state of knowledge in this field is quite at the beginning and our knowledge in all directions is poor. It cannot hurt to examine carefully the materials aspect of anything used which produces nuclear reactions. However, it is probably the surface more than the interior of the electrode and its material characteristics which control the phenomena.

That the phenomena are fundamentally sporadic and adventicious. Without any known changes in the conditions we can pass from active to non-active and as a matter of time of an electrode; or, i.e., it can switch on (thus, an electrode can be inactive for 30 or 40 hours, then be active for 10 hours, and then be inactive, again, all under the same conditions). We notice this both with tritium production and heat.

Although the electron microscopy is at its opening stages, it can be said that the results support the idea that if the surface is covered by dendritic growth, heat and tritium are more likely to be observed.

I hope these observations will aid you in making progress in what may be a new field of science.

Sincerely,

J. O'M. Bockris

JOMB/eas

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: J.C. Farmer, R.A. Van Konynenburg etal

ORGANIZATION: Lawrence Livermore National Laboratory

SHORT DESCRIPTION OF TYPE OF EXPERIMENT: Matched-cell electrochemical experiments to measure comparative heat output and ^3He and ^4He production in Pd electrodes using both light water and heavy water cells.

RESULTS AND COMMENTS:

Within the sensitivity of the experiments, ~~no excess~~ these was no significant change in temperature in either cell, once steady conditions were established. No ^4He was detected in either Pd cathode, with a detection limit of between 10^{10} and 10^{11} atoms per g. of sample. A small amount of ^3He was detected in the Pd from the D_2O cell, but it was of the order of the expected amount from charging with the level of tritium present in the initial heavy water. Neutron countrate remained at background.

These was no evidence for nuclear fusion.

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Palladium	Platinum
PURITY	(No record, but was purchased as an evaporation source)	
ALLOYING ELEMENTS	None detected by EDX analysis.	
SOURCE OF MATERIAL	Specialty Metals and Alloys, Grove City, Ohio (purchased July, 1978)	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Swaged and drawn to 1 mm diameter, & baked out in vacuum at 600°C for 3 hours	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	EDX of starting material — only Pd detected. Auger, SIMS, & XPS of surface after use. Elements detected included Si, S, Cl, C, Ca, Pd, O, Fe, and possibly Cu & Mg by Auger. SIMS detected H, Li, C, Na, Al, K, Ca, Fe, Pd, and possibly Ti, Cr, & Cu. XPS showed Fe, O, Ca, Pd, C, Si, and a trace of Al.	
NOTABLE OBSERVATIONS	No evidence of nuclear fusion.	

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	__X__no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	__X__no
HELIUM	_____yes	__X__no

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR:

Prof. J.O'M. Bockris

ORGANIZATION:

Chemistry Department
Texas A&M University, College Station, TX 77843-3255

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Tritium Analysis of the electrolyte using Liquid Scintillation Counter
Tritium Analysis of the gases after recombination outside the cell.
Heat measurements using calorimetry

RESULTS AND COMMENTS:

Nine out of about 30 samples have yielded large quantities of tritium in the electrolyte as well as in the gas phase.

Four out of about 20 samples have given excess heat in the range of 15-20%.

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A1

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	None	Washed in HCl

CHARACTERIZATION

Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS

No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO	Not measured		
EXPERIMENT YIELDED	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A2

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	None	Washed in HCl

CHARACTERIZATION

Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS

No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO	Not measured		
EXPERIMENT YIELDED	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A3

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	Annealed at 800°C, 8 hrs.	Washed in HCl

CHARACTERIZATION

Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS

No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO: Not measured

EXPERIMENT YIELDED			
	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A4

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	Annealed at 800°C, 8 hrs.	Washed in HCl

CHARACTERIZATION

Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS

No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO	Not measured		
EXPERIMENT YIELDED	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A5

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	Acid etch in 5M HCl 15 minutes	Washed in HCl

CHARACTERIZATION

Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS

No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO	Not measured		
EXPERIMENT YIELDED	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A6

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	Acid etch in 5M HCl 15 minutes	Washed in HCl

CHARACTERIZATION
Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS
No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO: Not measured

EXPERIMENT YIELDED			
	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A7

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	Electrochemical oxide removal, 2 hrs.	Washed in HCl

CHARACTERIZATION

Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS

No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO	Not measured		
EXPERIMENT YIELDED	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE A8

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	Electrochemical oxide removal, 2 hrs.	Washed in HCl

CHARACTERIZATION
Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS
No tritium in either electrode.

NOTABLE OBSERVATIONS
Tritium found in the outgoing gases.

D/METAL RATIO: Not measured

EXPERIMENT YIELDED			
	HEAT	-----YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X-YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE B3

	CATHODE	ANODE
MATERIAL	Pd - 3 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	Anneal 800°C in vacuum 8 hrs.	Washed in HCl

CHARACTERIZATION

RESULTS

NOTABLE OBSERVATIONS

D/METAL RATIO: Not measured

EXPERIMENT YIELDED,			
	HEAT	-----YES	--X--NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	--X--YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS

A9

	CATHODE	ANODE
MATERIAL	Pd - 1 mm diameter	Ni
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ
PREPARATION	None	Washed in HCl

CHARACTERIZATION

Before use Pd and Ni were analyzed by thermal desorption mass spectrometry by Los Alamos National Laboratory for tritium.

RESULTS

No tritium in either electrode.

NOTABLE OBSERVATIONS

D/METAL RATIO	Not measured		
EXPERIMENT YIELDED	HEAT	X -YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	-----YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE B8

	CATHODE	ANODE
MATERIAL	Pd - 3 mm diameter	Ni during charging Pt during calorimetry
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ Johnson Mathey
PREPARATION	Electrochemical oxide removal, 2 hrs.	Washed in HCl
CHARACTERIZATION		
RESULTS		
NOTABLE OBSERVATIONS		
D/METAL RATIO	Not measured	

EXPERIMENT YIELDED			
	HEAT	--X--YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	-----YES	--X-NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE B9

	CATHODE	ANODE
MATERIAL	Pd - 3 mm diameter	Ni during charging Pt during calorimetry
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ Johnson Mathey
PREPARATION	None	Washed in HCl

CHARACTERIZATION

RESULTS

NOTABLE OBSERVATIONS

D/METAL RATIO Not measured

EXPERIMENT YIELDED			
	HEAT	X YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	-----YES	-----NO
	HELIUM	-----YES	-----NO

1. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS
SAMPLE B1A

	CATHODE	ANODE
MATERIAL	Pd - 3 mm diameter	Ni during charging Pt during calorimetry
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Hoover and Strong Richmond, VA	Belleville Wire Co. Belleville, NJ Johnson Mathey
PREPARATION	Annealed at 1200°C for 12 hrs.	Washed in HCl
CHARACTERIZATION		
RESULTS		
NOTABLE OBSERVATIONS		
D/METAL RATIO	Not measured	

EXPERIMENT YIELDED	HEAT	--X--YES	-----NO
	NEUTRONS	-----YES	-----NO
	TRITIUM	-----YES	-----NO
	HELIUM	-----YES	-----NO

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: D.R. McCRACKEN

ORGANIZATION: ATOMIC ENERGY OF CANADA LIMITED

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

- ELECTROLYSIS OF LiOD/D_2O SOLUTIONS AT Pd CATHODES
- ^3He-BASED NEUTRON DETECTOR USED (EFFICIENCY = 1.6%, BACKGROUND: $8 \times 10^{-3}\ s^{-1}$)
- ^3T MEASUREMENTS (LIQUID SCINTILLATION COUNTING)
- CALORIMETRY WITH A CLOSED SYSTEM USING A CATALYTIC RECOMBINER

RESULTS AND COMMENTS:

- 12 DIFFERENT Pd CATHODES USED
- NEUTRON EMISSION $< 0.5\ n.s^{-1}$ or $< 0.05\ n.g^{-1}.s^{-1}$
- EXCESS POWER $< 0.13\ W.cm^{-3}$ or $< 10^{-2}\ W.g^{-1}$
- NO ^3T ACCUMULATION DETECTED

- GAS CHARGING WITH Ti SPONGE

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL Ti SPONGE

PURITY UNKNOWN

ALLOYING ELEMENTS

SOURCE OF MATERIAL UNKNOWN

PREPARATION
CAST OR WROUGHT
ANNEALED YES
ATMOSPHERE VACUUM
VACUUM
SPECIAL TREATMENT 600°C FOR 2 HOURS

CHARACTERIZATION
STRUCTURAL
CHEMICAL NONE
BEFORE OR AFTER USE
METHODS
RESULTS

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	~~_____~~no
NEUTRONS	_____yes	~~_____~~no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd WIRE (0.025x700cm)	Pt
PURITY	99.95%	
ALLOYING ELEMENTS	NONE	
SOURCE OF MATERIAL	JOHNSON-MATTHEY	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	AS RECEIVED	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	NONE	
NOTABLE OBSERVATIONS		

D / METAL RATIO ATTAINED > 0.72

EXPERIMENT YIELDED HEAT	_____yes	~~_____~~no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	__X__no
HELIUM	_____yes	~~__~~__no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd SHEET (0.1x1x9 cm)	Pt
PURITY	[illegible]	
ALLOYING ELEMENTS	0.13% Ag	
SOURCE OF MATERIAL	UNKNOWN	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	AS RECEIVED	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	YES BEFORE ATOMIC ABSORBTION 0.13% Ag	
NOTABLE OBSERVATIONS		

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	___X___no
NEUTRONS	_____yes	___X___no
TRITIUM	_____yes	___[illegible]___no
HELIUM	_____yes	___X___no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd ROD (0.7x9cm)	Pt
PURITY		
ALLOYING ELEMENTS	0.13% Ag	
SOURCE OF MATERIAL	UNKNOWN	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	ARC-MELTED IN AR, CAST IN WATER-COOLED COPPER MOLD, SWAGED, ANNEALED, CLEANED WITH ACETONE, AQUA REGIA AND WATER, ABRADED (600 GRIT)	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	 YES BEFORE ATOMIC ABSORBTION 0.13% Ag	

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_X_no
NEUTRONS	_____yes	_X_no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd ROD (0.3x12.5cm)	Pt
PURITY	VERY HIGH	
ALLOYING ELEMENTS	NONE	
SOURCE OF MATERIAL	CANADIAN NATIONAL RESEARCH COUNCIL AS HIGH-PURITY SPONGE	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	ARC-MELTED, CAST IN COPPER MOLD, SWAGED, ANNEALED, ELECTROPOLISHED, WASHED WITH METHANOL	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	YES BEFORE DC ARC SPECTROSCOPY 10 ppm Ag AS MAJOR IMPURITY	

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	_____yes	___X_no
TRITIUM	_____yes	___X_no
HELIUM	_____yes	_____no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd ROD (0.3x10 cm)	Pt
PURITY	99.95%	
ALLOYING ELEMENTS	NONE	
SOURCE OF MATERIAL	JOHNSON-MATTHEY (FUSION GRADE)	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	AS RECEIVED	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	NONE	
NOTABLE OBSERVATIONS		

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	__X__no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	__X__no
HELIUM	_____yes	_____no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	5 Pd TUBES (0.3x 25x 0.013)cm	Ni
PURITY	97%	
ALLOYING ELEMENTS	3% Ag	
SOURCE OF MATERIAL	UNKNOWN	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	UNKNOWN	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	NONE	

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd TUBE	Au
PURITY	HIGH	
ALLOYING ELEMENTS	NONE	
SOURCE OF MATERIAL	UNKNOWN	
PREPARATION		
CAST OR WROUGHT		
ANNEALED	NONE	
ATMOSPHERE		
VACUUM		
SPECIAL TREATMENT		
CHARACTERIZATION		
STRUCTURAL		
CHEMICAL	YES	
BEFORE OR AFTER USE	BEFORE	
METHODS	NEUTRON ACTIVATION	
RESULTS	100ppm Ag	

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd TUBE (3.3x4.8x0.25cm)	Pt
PURITY	UNKNOWN	
ALLOYING ELEMENTS		
SOURCE OF MATERIAL	UNKNOWN	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	NONE	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	NONE	
NOTABLE OBSERVATIONS		

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	_____yes	_____no X
TRITIUM	_____yes	_____no X
HELIUM	_____yes	_____no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd ROD (0.6x5 cm)	Pt
PURITY	99.95%	
ALLOYING ELEMENTS	NONE	
SOURCE OF MATERIAL	JOHNSON-MATTHEY (FUSION GRADE)	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	(AS RECEIVED)	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	NONE	
NOTABLE OBSERVATIONS		

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	__X__no
HELIUM	_____yes	_____no

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: M.M. Broer

ORGANIZATION: AT&T Bell Laboratories, Murray Hill, NJ

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

① electrolysis: attempt to verify P&F expmntal results: neutron detection

② D_2 gas pressurization of Pd-coated Ti, Pd + thermal cycling

RESULTS AND COMMENTS:

expmnt: ① no neutrons above background during 4 week measurement period in PdD system (LiOD solution; 3 rods): < 0.007 n/sec/g Pd, or $< 2.2 \times 10^{-24}$ (ddn) fusions/dd-pair/sec:.

10^6 × less than P/F; ≈5× less than Jones

this work presented at Santa Fe meeting / submitted to Phys. Rev. C and accepted

② same results; no bursts

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL Pd - coated Ti sponge

PURITY >99.9%

ALLOYING ELEMENTS /

SOURCE OF MATERIAL Ti sponge: Aldrich

PREPARATION
CAST OR WROUGHT
ANNEALED
ATMOSPHERE
(VACUUM)
(SPECIAL TREATMENT) heated Ti under vacuum before plating with Pd.

CHARACTERIZATION
STRUCTURAL
(CHEMICAL) qualitative: checked for reactivity with D_2 at room temperature (after above treatment)
BEFORE OR AFTER USE
METHODS
RESULTS

NOTABLE OBSERVATIONS heat of reaction (with D_2)

D / METAL RATIO ATTAINED not measured quantitatively

EXPERIMENT YIELDED HEAT	_____yes	_____no — not applic.
(NEUTRONS)	_____yes	___✓___no — steady / "bursts"
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

~~not~~ didn't look for

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd rods (4mm ϕ, 1mm ϕ)	Pt wire
PURITY	>99.99%	same
ALLOYING ELEMENTS	/	
SOURCE OF MATERIAL	AT&T Nassau Metal Works	
PREPARATION		
CAST OR WROUGHT	✓ (1mm rod ~~only~~ cast only)	
ANNEALED	✓ (4mm ϕ rod and one 1mm ϕ rod (cast + annealed) ✓)	
ATMOSPHERE	annealed at 900°C / 1hr flowing N_2	
VACUUM		
SPECIAL TREATMENT		
CHARACTERIZATION		
STRUCTURAL		
CHEMICAL		
BEFORE OR (AFTER USE)	Pd / D ratio	
METHODS	nuclear reaction analysis: $d(^3He, p)\alpha$	
RESULTS		

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED 0.7 – 0.8 (extracted)

EXPERIMENT YIELDED HEAT	_____yes	_____no	: no gross heat effects
NEUTRONS	_____yes	✓ no	
TRITIUM	_____yes	_____no	} not searched for
HELIUM	_____yes	_____no	

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: J. C. Hill and C. Stassis

ORGANIZATION: USDOE Ames Laboratory

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Electrochemical experiments with Pd cathodes using 0.1M LiOD in D_2O electrolyte.
Gas charging experiments with Ti metal and D_2 gas.
Search for gamma rays from $LaHD_2$.

RESULTS AND COMMENTS:

In the electrochemical experiments neutrons were monitored with a BF_3 counter and gamma rays with Ge detectors. The electrolyte temperature was monitored with a thermocouple. No radiation above background was observed and no unusual temperature excursions were seen.

In the gas charging experiments Ti was charged with high pressure D_2 gas at various temperatures. A number of cooling cycles down to liquid nitrogen temperatures were carried out. Neutrons were monitored with a BF_3 counter and none above background were observed.

Gamma rays from a sample of $LaHD_2$ were monitored to search for evidence of the reaction $p+d \rightarrow {}^3He$ + gamma. No gamma rays above background were observed.

The details of these experiments have been described in a paper submitted to the Journal of Fusion Energy. A copy is enclosed.

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Polycrystalline Pd rod	Pt
PURITY	99.95%	
ALLOYING ELEMENTS	None	
SOURCE OF MATERIAL	Government stockpile Originally from Johnson and Matthey	
PREPARATION	Powder arc melted under pure Ar to form bar.	
CAST OR WROUGHT	Bar swaged to form rod.	
ANNEALED	Rod vacuum heat treated at 600°C.	
ATMOSPHERE		
VACUUM		
SPECIAL TREATMENT		
CHARACTERIZATION		
STRUCTURAL		
CHEMICAL		
BEFORE OR AFTER USE		
METHODS		
RESULTS	No gamma or n radiation above background and no unusual temperature excursions.	

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED 1.8

EXPERIMENT YIELDED HEAT	_____yes	___X___no
NEUTRONS	_____yes	___X___no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no
Gamma & X-rays	_____yes	____X No

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Single crystal Pd rod	Pt
PURITY	99.95%	
ALLOYING ELEMENTS	None	
SOURCE OF MATERIAL	Johnson and Matthey	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Powder arc melted and then e^- beam melted. Next arc melted, swaged to rod and then zone refined with e^- beam. A $2\frac{1}{4}$" section was determined to be single crystal by x-ray analysis.	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	No gamma or n radiation above background and no unusual temperature excursions.	
NOTABLE OBSERVATIONS		

D / METAL RATIO ATTAINED 1.8

EXPERIMENT YIELDED HEAT	_____yes	___X__no
NEUTRONS	_____yes	___X__no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no
GAMMA & X-RAYS	_____Yes	___X__No

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL	Ti metal chips, 200 mesh powder, shavings up to 34g.
PURITY	I do not know. If information needed call J. Shinar at (515)294-8706 after 8/7/89.
ALLOYING ELEMENTS	None
SOURCE OF MATERIAL	Ames Laboratory
PREPARATION	All material made from 1/16-inch Ti sheet metal in our shop with ordinary tools.
CAST OR WROUGHT	
ANNEALED	
ATMOSPHERE	
VACUUM	
SPECIAL TREATMENT	
CHARACTERIZATION	
STRUCTURAL	
CHEMICAL	
BEFORE OR AFTER USE	
METHODS	
RESULTS	No neutrons above background during a number of temperature cycles.
NOTABLE OBSERVATIONS	

D / METAL RATIO ATTAINED 1.9

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL	$LaHD_2$ powder, 4 g
PURITY	Chemically pure
ALLOYING ELEMENTS	
SOURCE OF MATERIAL	Ames Laboratory
PREPARATION	
CAST OR WROUGHT	
ANNEALED	
ATMOSPHERE	
VACUUM	
SPECIAL TREATMENT	
CHARACTERIZATION	
STRUCTURAL	
CHEMICAL	
BEFORE OR AFTER USE	
METHODS	
RESULTS	No gamma radiation above background. Not gas charging. We just counted the $LaHD_2$ powder.
NOTABLE OBSERVATIONS	

D / METAL RATIO ATTAINED 2.0

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	_____yes	_____no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no
Gamma & x-rays	_____Yes	___X___No

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: Kelvin G. Lynn

ORGANIZATION: Brookhaven National Laboratory, Upton, New York 11973

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Calorimetry Measurements - 8 - D_2O cells - continuous monitoring
Mounted with thermal probes
Sensitivity ≈ 10-20 mWatts with approximately 10-30 Watts into cells

RESULTS AND COMMENTS:

All cells have high surface area Pt recombiners to eliminate D_2O loss by electrolysis; and avoid Tritium concentration. All these cells are mounted in a temperature controlled reservoir (±.1°C). Tritium measurements are made weekly. The electrodes are various diameters and metallurgical conditions (annealed, outgassed and formed to designed dimensions). Charging has been maintained continuously for over a month (some longer). No unexplainable heat output has occurred in our cells. One cell with an electrode that had been pre-deuterated has shown a small but significant increase in Tritium (4σ affect). This might be explained by tritium contamination in the D_2 gas used for charging. This is under investigaiton. Samples are presently being tested which are similar to that used by Texas A&M and Stanford. Presently no difference, when correctly measured, is observed between the heavy and light water cells. However, we do find a significant temperature difference in the cells, with constant currant.

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd	Pt mesh baskets and
PURITY	5'-9's	Pt wire and foil
ALLOYING ELEMENTS	-----	
SOURCE OF MATERIAL	Johnson-Matthey	
PREPARATION		
CAST OR WROUGHT		
ANNEALED		
ATMOSPHERE	vacuum & high purity Ar	
VACUUM		
SPECIAL TREATMENT	etched before insertion	
CHARACTERIZATION		
STRUCTURAL	TEM	
CHEMICAL	Scanning Auger Microprobe	
BEFORE OR AFTER USE		
METHODS	very brittle	
RESULTS		

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	____yes	__X__no
NEUTRONS	____yes	____no
TRITIUM	____yes	__X__no
HELIUM	____yes	____no

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL

PURITY

ALLOYING
ELEMENTS

SOURCE OF
MATERIAL

PREPARATION
CAST OR WROUGHT
ANNEALED
ATMOSPHERE
VACUUM
SPECIAL TREATMENT

CHARACTERIZATION
STRUCTURAL
CHEMICAL
BEFORE OR AFTER USE
METHODS
RESULTS

NOTABLE
OBSERVATIONS

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	__X__no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	__X__no
HELIUM	_____yes	_____nø

THE UNIVERSITY OF BRITISH COLUMBIA

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To: Office of the Director
Materials Research Laboratory
104 S South Goodwin Ave
Urbana IL 61801

From: M. Hayden
Dept of Physics
University of British Columbia
Vancouver BC CANADA

FAX: (217) 244-2278

Phone: (604) 222-2535

UBC Acct: 5-86558

Date: Aug 30/89
Time: 3:25 pm PDT

SUBJECT: "Cold Fusion" Survey

MESSAGE:

SIGNATURE:

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR:

M.E. Hayden, U. Närger, J.L. Booth

ORGANIZATION:

Department of Physics, University of British Columbia, Vancouver CANADA

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

"High Precision Calorimetric Search for Evidence of Cold Fusion Using in situ Catalytic Recombination of Evolved Gases."

① Developed a new type of calorimeter ["Inverse Flow Labarynth Calorimet

② Implemented the first "Recombination Cell"

The combination of these two proved to be ideally suited to cold fusion calorimetric measurements.

RESULTS AND COMMENTS:

A series of calorimeters lead to a final design (see Santa Fe proceedings and a further article to be published) which implements a recombination cell in a continuous flow calorimeter.

Ran various Pd samples for 4 months in various calorimeters. No sign of excess heat. "Best" result gave no sign of heat production to 0.3% level over 10 days for input powers in 4W to 18W range

---

Additional Notes

also did a μCF expt at TRIUMF in collaboration with J. H. Brewer. No anomalies observed [compared 3 similar samples]

i) Pd
ii) Pd / D ~.88
iii) Pd / H ~.88

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd	Pt
PURITY	99.9%	99.9%
ALLOYING ELEMENTS	———	———
SOURCE OF MATERIAL	Engelhard Industries	
PREPARATION	spark cut from ingot, ~10g bar	Aqua Regia
CAST OR WROUGHT	vacuum degassed at	
ANNEALED	600°C for 8 hours,	
ATMOSPHERE	washed in Aqua Regia	
VACUUM	Loaded (in 0.1M LiOD) &	
SPECIAL TREATMENT	with D prior to use	
CHARACTERIZATION		
STRUCTURAL		
CHEMICAL	Gravimetric determination	
BEFORE OR AFTER USE	of D/Pd ratio prior to	
METHODS	calorimetric measurements	
RESULTS		

No excess heat observed ± to the 0.3% level for input powers in the range 4W to 18W over a 10 day period. Similar results for several shorter runs with Pd bars and Pd wires.

NOTABLE OBSERVATIONS / Remarks

Sealed recombination cell.

D / METAL RATIO ATTAINED Typical 0.80 to 0.84. Highest 0.87

EXPERIMENT YIELDED HEAT	_____yes	__X__no
NEUTRONS	_____yes	_____no
TRITIUM	_____yes	__X__no
HELIUM	_____yes	_____no

Battelle
Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington U.S.A. 99352
Telephone (509) 376-8777
Telex 15-2874
Facsimile (509) 375-2718

September 14, 1989

Professor Howard Birnbaum, Director
Materials Research Laboratory
104 South Goodwin Avenue
Urbana, Illinois 61801

RECENT RESULTS OF "COLD FUSION" EXPERIMENTS AT PNL

Dear Professor Birnbaum:

In response to your request for information needed for your ERAB report, I am sending you the enclosed summary of a closed-cell electrolysis experiment, designed to determine whether integrated excess heat can be obtained. The cell has been working for about a month. As yet, we have seen no statistically significant excess heat, as illustrated by the attached plot, though there is a hint that the cell would be producing heat. The electrode is relatively large, however, (5 cm x 0.4 cm dia) and, according to the Fleischmann-Pons recipe may take up an extended time to become fully activated. We have held off sending you this report as long as possible in hopes we could report more definitive results.

Our electrode has not shown any "burst" activity.

Cordially yours,

John R. Morrey
Staff Scientist
Geochemistry Section

JRM/jeb

Enclosure: 1

MATERIALS USED IN COLD FUSION EXPERIMENT

PRINCIPAL INVESTIGATORS: Richard P. Allen, Russell H. Jones, M. D. Merz, John R. Morrey, Karl H. Pool, John F. Wacker

ORGANIZATION: Pacific Northwest DOE Laboratory

SHORT DESCRIPTION OF TYPE OF EXPERIMENT: A closed electrolysis cell with a Pt recombiner inside is being operated in conjunction with a flow calorimeter to determine heat balance. The cathode and anode are described on the accompanying sheet. The all-teflon cell holds about 500 cc of D_2O-0.1M ^6LiOD. Natural water circulates through the cell in a teflon-covered copper tubing. The following parameters are continuously monitored:

Water flow:	about 200 cc/min
Inlet temperature of coil:	about 25°C
Outlet temperature:	about 28°C
Cell temperature:	about 30°C
Ambient temperature:	20-25°C
Cell voltage:	slowly rising from 4 volts at the start to 19.5 volts after three weeks at a constant current of 1 amp.

Excess heat is calculated as outlined below:

Hin = Enthalpy added to system
Hout= Enthalpy taken from the system
$Hin + H(t_o) = H(t) + Hout$
$H(t_o)$=Hheat(t_o)=enthalpy content of system at time t_o
Hheat(t_o)=enthalpy stored in system as heat capacity at time t
H(t)=Hlat(t)+Hheat(t)=enthalpy content of system at time t
Hlat(t)=enthalpy stored in palladium electrode as PdD_x relative to D_2O
Hin=Helec+Hexe
Helec=Heat supplied by electric current
Hexe=Heat supplied by unknown (nuclear?) events
Hout=Hcond+Hbath
Hcond=Heat lost from bath by thermal convection/conduction
Hbath=Heat carried away from cell by circulating water
Hexe(t)=Hlat(t)+Dheat(T(t))+Hcond(t)+Hbath(t)-Helec(t)
T(t)=Temperature as a function of time
%Hexe(t)=Hexe(t)/Hin

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENT (STARTING AUG. 11, 1989)

	CATHODE	ANODE
MATERIAL	Pd	Pt gauze (not analyzed)
PURITY	99.84 based on ICP does not include C or Si	
ALLOYING ELEMENTS	Ti 540 ppm; Fe 381 ppm, Cr 162 ppm Pt 174 ppm; Zr 66 ppm; Sc 77 ppm.	
SOURCE OF MATERIAL	Master ingot cast from DOE inventory small tubing and Pd sponge	
PREPARATION	Vacuum/argon arc melted/swaged from 3/8" diam to 4 mm diam. Vacuum annealed at 800°C for 1 hr in 3 x 10^{-} to 6 x 10^{-8} torr. Stored in dry nitrogen backfilled desiccator until used.	
CHARACTERIZATION	ICP analysis for metallic impurities	
NOTABLE OBSERVATIONS	Upon 1-day rapid charging, 5 mm rod cracked badly at one location and on end near leads. Small cracks developed along length of rod.	

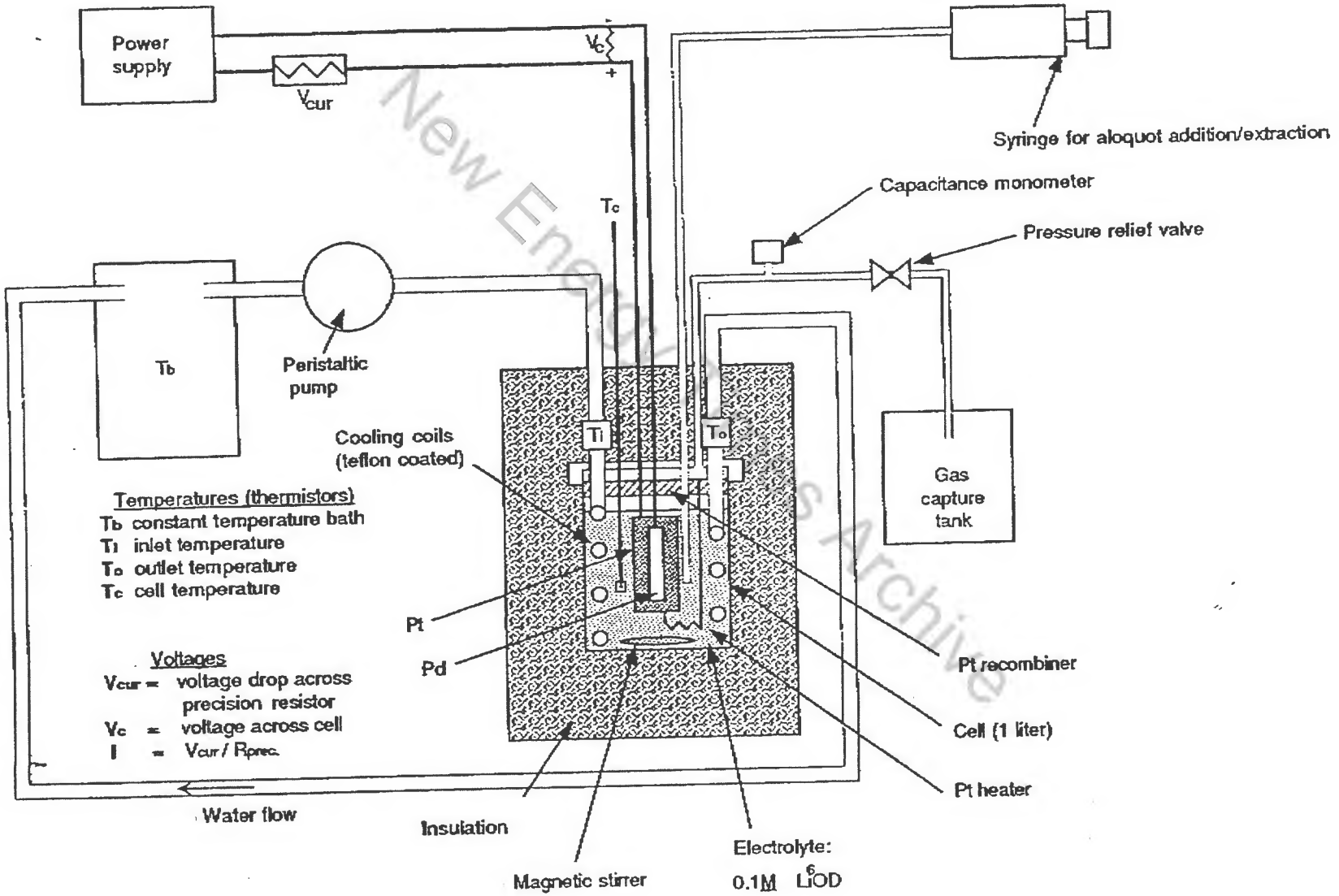
D/Metal RATIO ATTAINED D/Pd = 0.738 measured by weight gain.

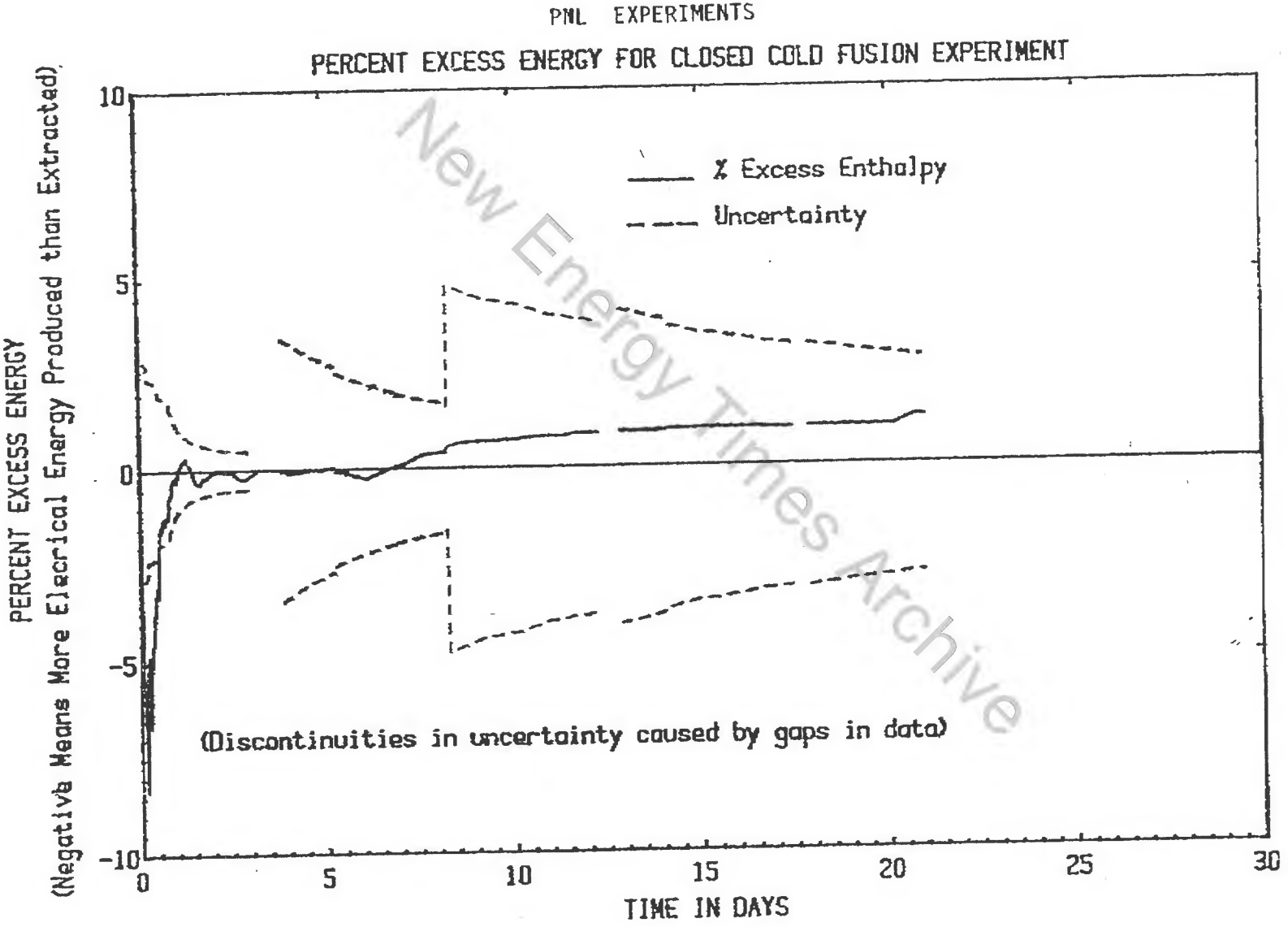
EXPERIMENT YIELDED

HEAT: None so far
NEUTRONS: None so far
TRITIUM: None so far
HELIUM: ?

PNL EXPERIMENTS

SCHEMATIC of D_2O EXPERIMENT





Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DATE: August 28, 1989
IN REPLY REFER TO: ADR:89–372
MAIL STOP: A114
TELEPHONE: (505) 667–1233
(FTS) 843–1233

Dr. Howard K. Birnbaum, Director
MATERIALS RESEARCH LABORATORY
University of Illinois at Urbana-Champaign
104 South Goodwin Avenue
Urbana, IL 61801

Dear Dr. Birnbaum:

In reply to your July 15 request for detailed information about cold fusion experiments, I enclose the collective responses of the Los Alamos National Laboratory. Soon after the Fleischmann-Pons announcement, the Los Alamos effort with electrochemical cells was much larger than is represented in this mailing. However, some of this early work was quickly performed with simple cell configurations and with any palladium that was available. And, of course, fusion products were not observed. Details of these more primitive measurements are not included.

Please let me know if I can be of further help. We too are anxious to resolve the cold fusion controversy.

Sincerely,

Reed J. Jensen
Deputy Associate Director
for Research

Cy: T. Claytor, WX–3/C914
M. Fowler, INC–11/J514
E. Garcia, INC–4/C346
S. Gottesfeld, MEE–11/D429
H. Menlove, N–1/E540
C. Orth, INC–11/J514
M. Paciotti, MP–DO/H809
E. Storms, MST–11/C348
R. Jensen, ADR/A114
CRM–4/A150 (2)
ADR File

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: E. Garcia / H. O. Menlove

ORGANIZATION: Los Alamos National Laboratory

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

The experiment involves placing 20-100g. of Ti alloy turnings in a stainless steel pressure vessel with 500 psi D_2. The pressure cylinder is cooled to liquid nitrogen temperature and allowed to warm to room temperature in a neutron detector. A typical experiment will last 10 days with 7-8 cooling cycles.

RESULTS AND COMMENTS:

Neutron bursts have been observed both when the cylinder is warming and after it is at room temperature. The neutrons are emitted in a burst lasting less than 100 μsec. These correlated neutron are on the scale of 100 neutrons or less.

Every effort has been made to systematically reproduce the neutron bursts but as of yet we obtain neutron emisson from only 50% of our sample cylinders. Neither the mechanism nor the critical factors controling neutron emission have been determined. Effort continue to pinpoint these factors.

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL Titanium alloy 6-6-2

PURITY weight % impurities O_2 0.15 H_2 0.003
N_2 0.02 C 0.02
H_2 0.003
Y 0.003

ALLOYING ELEMENTS weight %: Al - 5.79 Fe - 0.640
V - 5.43 Cu - 0.68
Sn - 1.92

SOURCE OF MATERIAL Teledyne Allvac
Ashcraft Ave.
Monroe, NC 28110

PREPARATION
CAST OR WROUGHT
ANNEALED
ATMOSPHERE
VACUUM
SPECIAL TREATMENT

Bar machined on lathe to produce turnings. Turnings washed with degreaser (methylene chloride) and methanol. Evacuated at 200°C for one hour to degas, backfilled at room temperature with 500 psi D_2.

CHARACTERIZATION
STRUCTURAL
CHEMICAL
BEFORE OR AFTER USE
METHODS
RESULTS

NOTABLE OBSERVATIONS Despite attempts to repoduce identical preparation conditions, neutron yield not reproducible.

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	XX yes	____XX no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL Titanium alloy 6-4

PURITY weight % impurities O_2 0.179 Si - 0.02 H_2 32 ppm
N_2 0.010 B <30 ppm
C 0.02 Y< 50 ppm

ALLOYING ELEMENTS weight %: Al 6.0 Fe 0.18
V 3.6
Cu < 0.01

SOURCE OF MATERIAL RMI Titanium
Niles, Ohio

PREPARATION
CAST OR WROUGHT
ANNEALED
ATMOSPHERE
VACUUM
SPECIAL TREATMENT

Bar machined on lathe to produce turnings. Turnings washed with degreaser (methylene chloride) and methanol. Evacuated at 200°C for one hour to degas, backfilled at room temperature with D_2.

CHARACTERIZATION
STRUCTURAL
CHEMICAL
BEFORE OR AFTER USE
METHODS
RESULTS

NOTABLE OBSERVATIONS Despite attempts to reproduce identical preparation conditions, neutron yield not reproducible.

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	_____no
NEUTRONS	XX yes	XX no
TRITIUM	_____yes	_____no
HELIUM	_____yes	_____no

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: SHIMSHON GOTTESFELD

ORGANIZATION: LANL, ELECTRONICS RESEARCH GROUP

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

ELECTROLYSIS FUSION EXPERIMENTS IN CELLS OF THE TYPE Pd / 0.1M LiOD / Pt

RESULTS AND COMMENTS:

7 CELLS RUN FOR 3-5 WEEKS EACH, WITH HIGHLY SENSITIVE NEUTRON & GAMMA DETECTORS. NO NEUTRONS (OR GAMMAS) ABOVE BACKGROUND COULD BE DETECTED IN AN AREA WITH LOW NEUTRON BACKGROUND (0.03 C/S). CURRENT DENSITIES EMPLOYED WERE IN THE RANGE 50-500 mA/cm

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd	Pt
PURITY	99.8% (Johnson Matthey)	
ALLOYING ELEMENTS	Li (in one calorimetric expt. ongoing)	
SOURCE OF MATERIAL	Stock LANL	Stock LANL
PREPARATION		
CAST OR WROUGHT	✓ Tubes (cold worked)	mesh or wire (most probably cold worked)
ANNEALED	& Rods – cast/annealed	
ATMOSPHERE	Ar	
VACUUM		
SPECIAL TREATMENT	Pd-Black deposition, on some	
CHARACTERIZATION		
STRUCTURAL		
CHEMICAL		
BEFORE OR AFTER USE		
METHODS		
RESULTS		

NOTABLE OBSERVATIONS

D / METAL RATIO ATTAINED 0.8 (from resistance)

EXPERIMENT YIELDED HEAT	_____yes	___X__no	
NEUTRONS	_____yes	___X__no	
TRITIUM	_____yes	___X__no	
HELIUM	_____yes	_____no	Not checked

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: T. N. Claytor

ORGANIZATION: Los Alamos National Laboratory, WX, N Division

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Neutron and tritium measurements were made on several completely solid state "cold fusion cells". The motivation for the cell design was to create a metal-insulator-semiconductor junction where a non-equilibrium condition could be produced by either electron injection or by diffusion of deuterium ions. Cells were constructed of palladium powder and slightly oxidized silicon powder pressed into a monolithic gas permeable pellet that was exposed to deuterium at 110 psia resulting in a D/Pd ratio of 0.7. The cells were pulsed at a high voltage (500 V) and at a low duty cycle to reduce joule heating.

RESULTS AND COMMENTS:

Neutron measurements were made at LANSCE (Los Alamos Neutron Scattering Center) because of the unique TOF (time of flight) detection system which allows a correlation (over a time interval of 1 to several thousand microseconds) to be made between the current pulse through the cell and the neutron output. Neutron production above background was detected on one cell however, the bank of helium-3 detectors at LANSCE was probably not sensitive enough to detect low levels of correlated output. In addition, the neutron activity seemed to occur in bursts although the LANSCE instrumentation was not specifically designed to follow stochastically uncorrelated time histories of the neutron output over long times.

The measurement of tritium levels in the cells was performed at the WX tritium handling facility. A new, clean, gas line was built to test for tritium in the cells. Tritium well above background was detected in one cell that had shown neutron activity. Other cells that showed little or no neutron emission gave results identical to the tritium level found in the fill gas.

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL Palladium, FINE Powder 1–10 μm dia.

PURITY 99.99 MAJOR impurities INCLUDE an oxide film, CO_2 + CO AND ADSorbed H_2O.

ALLOYING ELEMENTS Silicon with 100 Å oxide layer.

SOURCE OF MATERIAL

PREPARATION
CAST OR WROUGHT precipitation formed.
ANNEALED
ATMOSPHERE
VACUUM ——— Pd is pumped to remove most adsorbed H_2O
SPECIAL TREATMENT PUMP AND HEAT (1.5×10^{-7} Torr at 100 °C)

CHARACTERIZATION
STRUCTURAL SEM
CHEMICAL
BEFORE OR AFTER USE NONE
METHODS
RESULTS

NOTABLE OBSERVATIONS

EXPERIMENTS HAVE BEEN DIFFICULT TO REPRODUCE, SURFACE PREPARATION OR LACK OF, MAY STRONGLY INFLUENCE THE RESULTS.

D / METAL RATIO ATTAINED 0.7 as measured by gas uptake

EXPERIMENT YIELDED HEAT	____yes	✓ no	
NEUTRONS	✓ yes	____no	
TRITIUM	✓ yes	____no	
HELIUM	____yes	✓ no	D_2 CONTAINS 15ppm ^4H_e

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: Howard Menlove, gas cylinders prepared by Michael Paciotti

ORGANIZATION: LANL groups N1 and MPDO

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Degreased Ti alloy turnings were exposed to clean D_2 gas at up to 800 psi. Pressure cylinders were placed within high efficiency neutron detectors. Electronics records time correlated neutrons.

RESULTS AND COMMENTS:

Neutron bursts seen within a time window of a few microseconds from Ti alloy turnings exposed to clean D_2 gas. Bursts up to 50 emitted neutrons seen in Ti 662 alloy at room temperature uncorrelated with thermal cycling to 75°K.

Clean surfaces and D_2 gas felt important, but if overdone, deuteriding of metal is seen at temperatures $< 200°C$.

Moderate deuterding of metal ($D/Ti \leq 0.4$) appears to enhance the effectiveness of thermal cycling. Greater deuteriding kills the signal altogether.

No neutrons seen during the deuteriding process except at later times when all the available D_2 has been pumped by the Ti.

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: Edmund Storms and Carol Talcott

ORGANIZATION: Los Alamos National Laboratory

SHORT DESCRIPTION OF TYPE OF EXPERIMENT: Electrolytic charging of Pd using 0.2N LiOD electrolyte.

RESULTS AND COMMENTS: Two cells have produced tritium. Both had a sulfide layer applied by heating in H_2S+paraffin vapor. A total of 65 cells have been studied. Most of these cells have been used to study the effect of various impurities on the charging rate and limiting D/Pd ratio. Seven cells have been run in an attempt to duplicate tritium production.

MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS

MATERIAL: Pd from Johnson Matthey, Engelhard, and Marshall Laboratories
PURITY: Various arc-melted powers, sheet and wire have been used. Only a few of these materials have been analyzed so far.

Detected Elements	Johnson Matthey Powder(ppm)	Marshall Wire (ppm)
Ag	60	20
Fe	25	95
Al	20	35
Pt	35	140
Si	35	40
Au	<10	115
Na	65	<10

MATERIAL: D_2O from MSD Isotopes
PURITY: 99.9% D_2O. Elemental analysis is not yet available.

MATERIAL: Pt gauze
PURITY: Stock. Elemental analysis is not yet available.

ALLOYING ELEMENTS: Pd has been alloyed with Rh (10 at %), Li (1-4 at. %), C (1-3 at. %) and S (0.4 at. %), and Cu, Zn, S and C have been applied to the surface.

PREPARATION: The powders were arc-melted and rolled into a coin shape, ≈1.5cm diameter x ≈0.2 mm thick. Single crystals were also grown from pressed powders.

The sheet Pd was used as delivered as well arc-melted to produce a coin.

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL Titanium alloy. Ti 6 Al-6V-2Sn and Ti 6 Al-4V

PURITY

ALLOYING ELEMENTS Al 5.6%, V 5.4%, Sn 1.9%, Fe 0.58%, O 0.18%, C 0.02%, N 0.01%, H 0.0007%, ~~Rare~~ Cu 0.54%
(Spec sheet on the Ti 6-4 not available)

SOURCE OF MATERIAL Precision Rolled Products Inc via Steve Jones BYU

PREPARATION

CAST OR WROUGHT

ANNEALED Annealed AMS 4971C

ATMOSPHERE D_2 cleaned with molecular sieve trap.

VACUUM

SPECIAL TREATMENT Degrease lathe turnings with methylene chloride, then methanol, then pure water. Sorbtion pumping and baking at 80-100°C. Flush in hot, cleaned D_2

CHARACTERIZATION

STRUCTURAL → Heavy cold working due to turning

CHEMICAL

BEFORE OR AFTER USE

METHODS → Complete loss of strength for $D/Ti > 0.4$

RESULTS

Some cylinders had mixed Ti 662 and Ti 64, but Ti 662 has been seen to work separately.

NOTABLE OBSERVATIONS Bursts seen at room temperature and during thermal cycles. Bursts seen as high as 800 psi D_2 pressure and at <.01 psi. No neutrons seen during deuteriding while acoustic emission is very active.

D / METAL RATIO ATTAINED .05 to 1.4

EXPERIMENT YIELDED HEAT	✓ yes	no
NEUTRONS	✓ yes	no
TRITIUM	yes	no
HELIUM	yes	no

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: Malcolm Fowler - INC-11 Ed Garcia - INC-4
Howard Menlove - N-1 Tony Mayer - MST-7

ORGANIZATION: Los Alamos National Laboratory
Los Alamos, NM 87545

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Experiments where Ti or Ti alloys are pressurized with D_2 gas then cycled between 77°K and Room Temperature Neutron Counting only.

RESULTS AND COMMENTS:

In some cases, neutron burst emission is observed as the pressurized samples warm from 77°K to Room temperature. Generally the emission occurs as one or two bursts that take place near -30°C. The size of the bursts are variable but can be as large as 100 neutrons emitted in a time short compared to the 128 μsecond gate counting time. The results are not reproduceable although we seem to have better luck with fresh turnings of Ti-662 alloy.

We have also seen some random emission from a few samples as well as a few bursts at room temperature.

The wire was used as delivered.

A few samples of coin were annealed in vacuum to determine the effect of this treatment. Most were not annealed.

CHARACTERIZATION: A tritium producing electrode has been examined using ESCA, Auger and photomicrographic techniques. A few other electrodes have been examined by photomicrographic techniques. Lack of resources have limited such examinations.

NOTABLE OBSERVATIONS:
1. Very small concentrations of impurities change the interaction between Pd and D. Addition of S, Li or Rh improves the interaction while carbon reduces deuterium uptake. Surface C, Zn or Cu significantly reduces deuterium uptake.
2. Surface S or Ni causes recombination when exposed to oxygen in the air resulting in self heating.
3. There is a combination of C and S on the surface that can produce tritium.
4. Tritium production occurs on the surface, not in the bulk. Therefore, the bulk D/Pd ratio appears to have limited significance.

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: M. Fowler, C. Orth, G. Miller, C. Longmire, J. Wilhelm } INC-11

ORGANIZATION: Los Alamos National Laboratory

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

A whole series of electrochemical experiments using Pd or Ti Cathodes, 0.1 m LiOD in D_2O, and Pt anodes.

RESULTS AND COMMENTS:

- No measurable neutrons (Counted in an 8 tube well ($\epsilon = \sim 4\%$) Counter).
- No measurable (gamma ray Counted with ORTEC GAMMA-X detector.
- No measurable Pd X-rays
- About a factor of 3 increase in Tritium Concentration probably due to electrolytic Concentration in the D_2O.

II. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL Pure Ti, Pd, Ti 662 and Ti 64 alloy

PURITY ?

ALLOYING ELEMENTS Ti 6-4 = 6% Al, 4% V
Ti 6-6-2 = 6% Al, 6% V, 2% Sn

SOURCE OF MATERIAL Various Supplies as LANL Stock.

PREPARATION
CAST OR WROUGHT
ANNEALED
ATMOSPHERE
VACUUM Generally Vacuum degassed @ ~ 200°C for 1 hr then
SPECIAL TREATMENT Cooled to Room Temperature before Pressurizing to 40 Atm (600 PSI) with D_2

CHARACTERIZATION
STRUCTURAL
CHEMICAL
BEFORE OR AFTER USE
METHODS
RESULTS

NOTABLE OBSERVATIONS Samples cycled between 77°K and Room temperature
Some neutron bursts, generally at −30°C. No neutrons in coincidence with Acoustic signals or Ionization events in the D_2.
6 cooling cycles is longest that any cylinder produced neutrons.

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	__X__ yes	______ no
NEUTRONS	______ yes	______ no
TRITIUM	______ yes	______ no
HELIUM	______ yes	______ no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Ti loaded with 5 Ci ^3T	Pt Mesh
PURITY	—	
ALLOYING ELEMENTS	Ti on Copper backing 1.25" diameter	
SOURCE OF MATERIAL	Neutron generator target	

PREPARATION
CAST OR WROUGHT
ANNEALED
ATMOSPHERE
VACUUM
SPECIAL TREATMENT
} None

CHARACTERIZATION
STRUCTURAL
CHEMICAL
BEFORE OR AFTER USE
METHODS
RESULTS

NOTABLE OBSERVATIONS: Electrolysis Run for ~ 60 hrs at a total current of 400 ma. 0.1 M LiOD in D_2O

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	____yes	X no
NEUTRONS	____yes	X no
TRITIUM	____yes	X no
HELIUM	____yes	X no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd	Pt wire or Mesh
PURITY	?	
ALLOYING ELEMENTS	?	
SOURCE OF MATERIAL	LANL Stock	
PREPARATION		
CAST OR WROUGHT	Used as received	
ANNEALED		
ATMOSPHERE		
VACUUM		
SPECIAL TREATMENT	Arc melted & Cast under Argon.	
CHARACTERIZATION		
STRUCTURAL		
CHEMICAL		
BEFORE OR AFTER USE	– None –	
METHODS		
RESULTS		

NOTABLE OBSERVATIONS Cast Pd electrode showed signs of surface distortion after long electrolysis (>10 days) at high current, (>500 mA/cm^2)

D / METAL RATIO ATTAINED ——

EXPERIMENT YIELDED HEAT	_____yes	__X__no
NEUTRONS	_____yes	__X__no
TRITIUM	_____yes	__X__no
HELIUM	_____yes	__X__no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	TiD_2 $(D/Ti = 1.7)$	Pt Mesh
PURITY		
ALLOYING ELEMENTS		
SOURCE OF MATERIAL	Prepared at LANL	
PREPARATION		
CAST OR WROUGHT		
ANNEALED		
ATMOSPHERE		
VACUUM		
SPECIAL TREATMENT		
CHARACTERIZATION		
STRUCTURAL		
CHEMICAL		
BEFORE OR AFTER USE		
METHODS		
RESULTS		

NOTABLE OBSERVATIONS Electrolysis in 0.1 M LiOD in D_2O run for 4 hrs @ 100 mA/cm2

D / METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	_____yes	___X___no
NEUTRONS	_____yes	___X___no
TRITIUM	_____yes	___X___no
HELIUM	_____yes	___X___no

OAK RIDGE NATIONAL LABORATORY
OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831

August 31, 1989

Dr. Howard K. Birnbaum
Office of the Director
Materials Research Laboratory
104 South Goodwin Avenue
Urbana, Illinois 61801

Dear Dr. Birnbaum:

In response to your request of July 15, 1989, enclosed are cold fusion reports from the four active experimental groups at the Oak Ridge National Laboratory (ORNL).

If you have any questions, please contact me at (615)574-4321.

Sincerely,

Bill R. Appleton

Bill R. Appleton
Associate Director

BRA:jcm

cc: J. B. Ball
W. Fulkerson
R. K. Genung
M. L. Poutsma
M. W. Rosenthal
M. J. Saltmarsh
J. Sheffield
J. O. Stiegler
A. W. Trivelpiece

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: C. D. Scott

ORGANIZATION: Oak Ridge National Laboratory, Chemical Technology Division

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Electrochemical cells utilizing Pd cathodes and Pt anodes in 0.1 to 0.2 *N* LiOD were used. The electrolysis cell was insulated and a cooling jacket with circulating water used for heat removal. The neutron flux and gamma ray spectra were measured, and periodic electrolyte sampling for T was carried out. Electrical current densities of 100 to 600 mA/cm^2 Pd were used. In all completed experiments the cells were open, allowing the evolved D_2 and O_2 gasses to leave the cell. In the current, uncompleted experiment, an internal recombiner is being used so that the system is completely closed.

RESULTS AND COMMENTS:

In some of the open-system experiments, apparent excess power was detected for periods of several hours, usually in the range of 5 to 10%. However, during one 12-hour period an apparent imbalance of up to 50% was seen. These excursions, which were transitory, appeared after the current density was increased. They could be extended by perturbing the system, for example changing the electrolyte temperature or increasing the electrolyte concentration. There were two occasions, uncorrelated with any excess power observations, where the neutron detector count rate exceeded average background values by greater than three standard deviations. Recent, very preliminary results from a closed system, which includes a recombiner, are also indicating a power imbalance of ~5%, although this experiment is not yet complete.

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd	Pt wire
PURITY	99.9%	99.9+%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Materials Research Corp.	Englehard Corp.
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Cast in Ar, swaged to appropriate diam, then annealed at 950°C under vacuum for 4 hours	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	0.28-cm diam x 8-cm cylinder	24 ga wire
NOTABLE OBSERVATIONS	Periods of several hours of apparent excess power in the range of 5 to 10% were observed after changes to experimental conditions.	

D/METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	X yes	____ no
NEUTRONS	____ yes	X no
TRITIUM	____ yes	X no
HELIUM	____ yes	X no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Pd, 0.28-cm diam x 9 cm	28 ga Pt wire
PURITY	99.9%	99.9+%
ALLOYING ELEMENTS	None	None
SOURCE OF MATERIAL	Materials Research Corp.	Englehard Corp.
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Cast in Ar, swaged to appropriate diam	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	0.28-cm diam x 9-cm cylinder	28 ga wire
NOTABLE OBSERVATIONS	Neutron count rate exceeded three standard deviations of the average background during a 4-hour period.	

D/METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	____ yes	__X__ no
NEUTRONS	____ yes	__X__ no
TRITIUM	____ yes	__X__ no
HELIUM	____ yes	__X__ no

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: D. P. Hutchinson

ORGANIZATION: Oak Ridge National Laboratory, Physics Division

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Four calorimetry cells were operated for a period of over 1800 hours with two cells using 6.35-mm diam. x 10-cm long palladium cathodes in a 0.2 M ^{6}LiOD electrolyte, one cell with a similar cathode in a 0.1 M ^{6}LiOD electrolyte solution and one cell containing a cast 1.27-cm diam. x 10-cm palladium rod in a 0.2 M electrolyte. All cells were constructed with an electrolyte volume of 300 cm^3 and a 54 mm o.d. quartz envelope. No D_2/O_2 recombination was assumed. All of the cells contained a platinum wire spiral wound anode with a diameter of 30 mm. Two of the cells had 6.35 mm palladium rod electrodes precharged in D_2 gas to a stoichiometry of 0.6.

RESULTS AND COMMENTS:

The cells were operated at a current density of 50 mA/cm^2 for 48 hours and then at a current density of 250 mA/cm^2 for over 1800 hours. Three of the cells have remained in power balance within the experimental uncertainty of ± 1 watt for the duration of the experiments. However, one of the cells, containing one of the non-precharged rods, exhibited an apparent power deficit of approximately 2 watts for the first 75 hours of operation, followed by an apparent power excess of approximately 3 watts for a 600-hour period beginning 150 hours after the beginning of the experiment. From 75 hours to 150 hours, the cell was in power balance. Shortly after the excess power was indicated, the cell was placed in a neutron counter containing a pair of NE213 scintillator detectors with pulse shape discrimination. The neutron emission level of the cell was determined to be less than 1×10^{-24} neutrons/s/D-D pair. Various changes were made to the cell during the period of apparent imbalance to improve the calorimetry measurement and to determine the effect of changes on the observation. The imbalance was not significantly affected by the bath temperature changes between 13 and 20°C, but disappeared with a reduction in temperature to 5°C. The apparent excess reappeared when the temperature was raised to 13°C, disappeared when the temperature of the bath was once again lowered to 5°C, and did not return after a temperature increase to 13°C. Subsequently, this cell has remained in power balance for 1100 hours. We are planning a thorough material analysis of the rods following the termination of these initial experiments in September 1989 and attempting to reproduce these observations.

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Palladium (6.35-mm diam x 10-cm long rod)	Platinum wire, #20 gauge
PURITY	99.96%	
ALLOYING ELEMENTS	None	
SOURCE OF MATERIAL	Johnson-Matthey	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Wrought Vacuum annealed @ 900°C for 2 hours	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	In progress	
NOTABLE OBSERVATIONS	The cell that exhibited an apparent power imbalance was accidentally contaminated with a stainless steel screw in the electrolyte during assembly. It was not possible to remove the screw after the experiment began, and it remained in the cell for the entire duration. The significance of this is not known.	
D/METAL RATIO ATTAINED	As yet undetermined	

EXPERIMENT YIELDED HEAT	_____ yes	_____ no (See text)
NEUTRONS	_____ yes	_X_ no
TRITIUM	_____ yes	_X_ no
HELIUM	_____ yes	_X_ no

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: E. L. Fuller, Jr.

ORGANIZATION: Oak Ridge National Laboratory, Metals and Ceramics Division

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

A power calorimeter designed around a 40-gallon (water) temperature bath, controlled to 0.01°C or better, is currently in operation with four cells. Up to eight cells can be accommodated.

Each cell holds 75 mL of electrolyte (either 0.1 N $^6LiOD/D_2O$ or 0.1 N $^6LiOH/H_2O$), and is equipped with a mechanical stirrer and calibration heater. The calorimeter cells can be operated over three power output ranges: (1) with an air jacket for very low power, (2) with a water jacket for intermediate power output, and (3) with no jacket (i.e., direct connection of the cell to the bath) for the highest power output.

RESULTS AND COMMENTS:

In this experiment, the cells are brought on-line two at a time; one with light water and one with heavy water. The current is connected in series between the two cells. This has the advantage of not only subjecting the cells to identical currents, but also providing a check on the electrolysis rate and the amount of makeup water required.

No excess heat or tritium (above background) has been detected in these experiments to date.

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Palladium	Ni Rod
PURITY	99.95%	
ALLOYING ELEMENTS	None	
SOURCE OF MATERIAL	Johnson-Matthey	
PREPARATION CAST OR WROUGHT	Wrought	
ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Annealed at 600°C for 4 hours	Annealed at 600°C for 4 hours
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	In progress	
NOTABLE OBSERVATIONS	During the initial stages of electrolysis, a fine, black powder (probably nickel oxide) formed in the cell.	
D/METAL RATIO ATTAINED	Undetermined; experiment in progress.	

EXPERIMENT YIELDED HEAT	____ yes	__X__ no
NEUTRONS	____ yes	__X__ no
TRITIUM	____ yes	__X__ no
HELIUM	____ yes	__X__ no

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Palladium	Pt wire
PURITY	>99.9%	
ALLOYING ELEMENTS	None	
SOURCE OF MATERIAL	In-house	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Cold-cast under an Ar atmosphere in a copper mold	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	In progress	
NOTABLE OBSERVATIONS	With the calorimeter design employed in this experiment, mechanical stirring is essential for obtaining a correct cell output power from the thermistor response (even at 200 mA/cm^2).	
D/METAL RATIO ATTAINED	Undetermined; experiment in progress.	

EXPERIMENT YIELDED HEAT	_____ yes	__X__ no
NEUTRONS	_____ yes	__X__ no
TRITIUM	_____ yes	__X__ no
HELIUM	_____ yes	__X__ no

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: E. L. Fuller, Jr.

ORGANIZATION: Oak Ridge National Laboratory, Metals and Ceramics Division

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Six electrochemical cells using a variety of cathodes (different materials, sizes, or treatments) were operated in an arrangement suitable for neutron counting with BF_3 detectors. The cathodes for the six cells were as follows: (1) two cold-cast, swaged 3.1-mm-diam by 5-cm palladium rods, (2) one cold-cast 6.25-mm-diam by 5-cm palladium rod, (3) one 44-g cold-cast palladium "button," (4) one cold-cast 10.9-mm-diam by 3-cm palladium rod, and (5) one cold-cast 6.25-mm-diam by 5-cm titanium rod. The anodes were either platinum or platinum/rhodium wire and the electrolyte was 0.1 N ^{6}LiOD. All cells were operated at current densities ranging from 25 to 300 mA/cm^2.

RESULTS AND COMMENTS:

Initially, a single BF_3 detector (~2% efficiency for Cf252 fission neutrons with ca. 200 counts per hour background), immersed in a water moderating bath, was used to monitor possible neutron emission from six surrounding electrochemical cells. After having observed an increase in the count rate of this detector, lasting about 18 hours and persisting even with the electrochemical cells removed from the bath, a second BF_3 detector was introduced to monitor the background level. Pulse height discrimination was used with both detectors to reduce noise counts, and a multichannel analyzer was used to observe the overall BF_3 output. Subsequently two unexplained increased in the BF_3 detector count rate were recorded while the experiment was unattended. In both of these instances the background monitor detector count rate remained constant. In one of these instances the count rate increased for about 24 hours. This incident was somewhat similar to the one that had led earlier to the introduction of the background monitor detector and a subsequent one in which the detector became very noisy for about 24 hours (the source of this noise was not discovered. In the second instance of increased count rate, two increases were recorded, lasting approximately 45 and 60 minutes, respectively, with the background monitor detector showing no corresponding increases. Such large increases in recorded count rates wee occasionally observed in both counters and were caused by microphonics. Although the recorded increases in count rate while the experiment was unattended could have been caused by neutrons from the cells, not enough control existed in the experiment to conclude that this was definitely the case. The cell with a 44 gram electrode exploded (presumably $D_2 + O_2$) and since that date neither of the BF3 detectors have shown any variation above background (for about two months).

I. MATERIALS USED FOR ELECTROCHEMICAL EXPERIMENTS (please complete one sheet for each experiment)

	CATHODES	ANODES (Corresponding)
MATERIAL	Palladium, Titanium	Platinum or Platinum/Rhodium
PURITY	≥99.9%	
ALLOYING ELEMENTS	None	
SOURCE OF MATERIAL	In-house	
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	Cold-cast under Ar using copper molds. 3.1-mm rods were swaged from a single 6.25-mm rod.	
CHARACTERIZATION STRUCTURAL CHEMICAL BEFORE OR AFTER USE METHODS RESULTS	B-phase slowly undergoing a phase transition, but with no detectable α-phase (by x-ray diffraction). One electrode showed a large rhenium level after use (by glow-discharge mass spectrometry).	
NOTABLE OBSERVATIONS	The after-use palladium electrodes examined to date have shown a remarkable ability to retain deuterium. After several months, the D/Pd ratio in one electrode remained above 0.5.	
D/METAL RATIO ATTAINED	≥0.82 for Pd; not determined for Ti.	

EXPERIMENT YIELDED HEAT	____ yes	__X__ no	
NEUTRONS	____ yes	____ no	(see text)
TRITIUM	____ yes	__X__ no	
HELIUM	____ yes	__X__ no	

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: J. G. Blencoe

ORGANIZATION: Oak Ridge National Laboratory, Chemistry Division

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Investigation of reactions between high-purity palladium and deuterium at high gas pressures and low temperatures.

RESULTS AND COMMENTS:

A series of experiments were conducted to elucidate reactions between Pd and D_2 at high pressures and low temperatures. In our initial Pd-D_2 experiment, 0.7 grams of 0.1-mm thick palladium ribbon (Table 1) was wrapped around the tip of the lower (sample) thermocouple and sheathed with platinum foil. Pressurization of this sample to 380 MPa with 99.87% D_2 gas produced a rapid temperature rise (from 27 to 60°C) that was much larger than a simultaneous temperature rise (from 27 to 32°C) recorded by the reference thermocouple. This thermal anomaly decayed to the bath temperature after 12 minutes. During and for five days after this pressurization, the neutron flux was monitored at sampling times ranging from 6 seconds to 10 minutes. No sustained neutron flux above background was observed. Subsequent pressurizations of D_2 gas alone and 0.7 grams of palladium with H_2 gas produced thermal effects similar to the initial run, indicating that the thermal anomaly observed during our first Pd-D_2 experiment can be attributed to (1) PV work accompanying gas pressurization, (2) heat released during the formation of palladium deuteride, and (3) the somewhat different geometries of the sample and reference thermocouples.

The pressure vessel was then packed with 7.0 grams of palladium in the form of (1) ~1 gram of 0.1-mm thick ribbon wrapped around the sample thermocouple, and (2) ~6 grams of 3-mm x 3-mm cut pieces of 0.1-mm thick ribbon filling the space between the sample and reference thermocouples. Upon initial pressurization to 380 MPa with D_2 gas, thermal effects similar to those described above were observed. During the next three days, the temperature of the vessel was (1) reduced to -78°C using dry ice, and subsequently (2) allowed to warm slowly to room temperature. This was done because several investigators (e.g., Perminov et al., 1952) have reported greatly enhanced solubility of hydrogen in palladium at cryogenic temperatures. Finally, the sample was depressurized to a 20 micron vacuum at room temperature for one day and repressurized to 350 MPa for two days. As in the first Pd-D_2 experiment, no sustained neutron flux above background was observed.

I. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL	Palladium
PURITY	99.97 wt. %
ALLOYING ELEMENTS	See attached table.
SOURCE OF MATERIAL	Martin Marietta Energy Systems Stores, Y-12 Plant, Oak Ridge, Tennessee
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM SPECIAL TREATMENT	See attached table.
CHARACTERIZATION	
STRUCTURAL	None.
CHEMICAL	See attached table.
BEFORE OR AFTER USE	Before.
METHODS	See attached table.
RESULTS	See attached table.
NOTABLE OBSERVATIONS	Deuterium continued to effuse from the palladium long after experimentation.

D/METAL RATIO ATTAINED

EXPERIMENT YIELDED HEAT	X* yes	____ no	____ don't know
NEUTRONS	____ yes	X no	____ don't know
TRITIUM	____ yes	____ no	X don't know
HELIUM	____ yes	____ no	X don't know

*Heat released is believed to be entirely chemical (not nuclear).

Table 1. Analysis of 99.97% Palladium Ribbon[a,b]

Ag	6	As	0.7	Au	1	B	12	Ba	<0.2	Be	0.20	Bi	<0.1
Br	<0.04	Ca	73	Cd	<0.20	Co	0.02	Cs	<0.03	Cu	9	Fe	19
Ga	<0.03	Ge	<0.02	Hf	<0.05	Hg	<0.08	In	<0.01	Ir	3	K	0.50
Mg	0.70	Mo	2	Na	0.07	Nb	0.20	Ni	3	Os	<0.05	P	0.30
Pb	0.7	Pt	52	Rb	<0.01	Re	<0.02	Rh	29	Ru	<0.06	S	3
Sb	<0.05	Sc	0.02	Se	<0.01	Si	54	Sn	<0.30	Sr	0.03	Ta	<5
Te	5	Th	0.06	Ti	2	Tl	<0.02	U	0.20	W	0.60	Y	<0.02
Zn	2	Zr	4	Cl	0.40	F	<0.01	I	<0.03	Ce	<0.10	Dy	<0.04
Er	<0.04	Eu	<0.02	Gd	<0.05	Ho	<0.01	La	<0.04	Lu	<0.01	Nd	<0.05
Pr	<0.01	Sm	<0.04	Tb	<0.01	Tm	<0.01	Yb	<0.04				

[a]Concentrations of all trace elements reported in ppm.

[b]Analyzed by DC-arc spectrograph at the Y-12 Plant, Oak Ridge, TN. Masked elements include Al, Cr, Mn, and V. Prior to use in experimentation, the ribbon was: cleaned in concentrated aqua regia; heated to 600°C under high vacuum (10^{-5} torr); exposed to 0.05 MPa D_2 gas at 600°C for 15 minutes; held at 600°C under high vacuum (10^{-5} torr) for one hour; cooled back to room temperature; and finally, stored under 99.999% argon. Additionally, to preclude surface contamination prior to experimentation, the ribbon was loaded into the pressure vessel under 99.999% argon.

MATERIALS USED IN COLD FUSION EXPERIMENTS

PRINCIPAL INVESTIGATOR: J. G. Blencoe

ORGANIZATION: Oak Ridge National Laboratory, Chemistry Division

SHORT DESCRIPTION OF TYPE OF EXPERIMENT:

Investigation of reactions between high-purity titanium and deuterium at high gas pressures and low temperatures.

RESULTS AND COMMENTS:

A single Ti-D_2 experiment has been conducted to test the claim that special disequilibrium pressure-temperature conditions will induce cold fusion in Ti-D_2 samples.

Starting materials for the Ti-D_2 experiment were (1) 1.6 mm-diameter titanium wire that was chemically polished in an acid bath prior to experimentation (Table 1), and (2) high-purity D_2 gas. The titanium wire (a total of 9 grams) was cut into 0.5- to 2.5-cm lengths before being subjected to high D_2 pressure. To prevent surface oxidation, the titanium wire was stored and transferred under 99.999% argon.

During the Ti-D_2 experiment, data were collected on pressure, temperature, and detector counts. In detail, the sequence of events was as follows: (1) pressurization to 380 MPa; (2) after approximately 29 hours (to compensate for a slow gas leak), repressurization to 380 MPa; (3) cooling to -78°C using dry ice, which produced a drop in pressure from 380 to 320 MPa; (4) slow warming to approximately 10°C over a 20-hour period, (5) depressurization to 80 MPa; (6) cooling to -196°C using liquid nitrogen, which produced a drop in pressure from 80 to 40 MPa; (7) slow warming to approximately -120°C over a 21-hour period, which produced an increase in pressure from 40 to 60 MPa; (8) rapid warming to 27°C over a 6-hour period, which produced an increase in pressure from 60 to 70 MPa; and finally (9) rapid cooling to -196°C, followed by rapid warming to 27°C, all within the space of an hour. After 105 hours of experimentation, the D_2 was vented from the pressure vessel and a vacuum pump was used to remove any residual gas.

The average detector count rate for the 105 hours of experimentation was 532.1 counts/hour. Approximately 80 hours after the experiment began, the count rate increased to ~590 counts/hour and remained at that level for about 5 hours. This increase cannot be due to random fluctuations in the average count rate and is potentially significant. If the increase can be attributed to neutrons emitted by the Ti-D_2 sample, this would correspond to an emission rate of ~1000 neutrons/hour.

However, because we cannot completely verify that our neutron detectors were operating properly during this 5-hour period, it cannot be claimed that cold fusion neutrons were observed. We are planning to repeat our Ti-D_2 experiment with an improved detector system where (1) moderated neutrons will be detected by two totally independent detector systems, (2) the background count rate will be monitored continuously by a similar and independent detector system placed nearby, and (3) additional shielding will be provided in an attempt to improve the neutron sensitivity of our detector systems.

I. MATERIALS USED FOR GASEOUS CHARGING EXPERIMENTS (please complete one sheet for each experiment)

MATERIAL	Titanium
PURITY	99.91 wt. %
ALLOYING ELEMENTS	See attached table.
SOURCE OF MATERIAL	Commercial source (See attached table.)
PREPARATION CAST OR WROUGHT ANNEALED ATMOSPHERE VACUUM	None.
SPECIAL TREATMENT	See attached table.
CHARACTERIZATION	
STRUCTURAL	None.
CHEMICAL	See attached table.
BEFORE OR AFTER USE	Before.
METHODS	See attached table.
RESULTS	See attached table.
NOTABLE OBSERVATIONS	No visible evidence of any reaction between the titanium and deuterium.
D/METAL RATIO ATTAINED	Not determined.

EXPERIMENT YIELDED HEAT	____	yes	X	no	____	don't	know
NEUTRONS	____	yes	X	no	____	don't	know
TRITIUM	____	yes	____	no	X	don't	know
HELIUM	____	yes	____	no	X	don't	know

Table 1. Analysis of 99.91% Titanium Wire[a,b]

C	35.0	N	15.0	O	500.0	Mg	<5.0	Si	<5.0	Al	20.0	S	10.0
Ca	5.0	V	5.0	Cr	40.0	Mn	30.0	Fe	150.0	Ni	40.0	Cu	30.0
Sn	10.0	Pb	20.0	Bi	<10.0								

[a]Concentrations of all trace elements reported in ppm.

[b]Lot analysis reported by vendor (#22/58107, Materials Research Corp., Orangeburg, NY). Prior to use in experimentation, the wire was chemically polished in an acid bath (nitric + lactic + hydrofluoric acid in a 5:5:4 ratio) to remove all surficial titanium oxide.